National Institute for Health and Care Excellence

Guideline version (Draft)

Indoor air quality at home

[3.1] Evidence review for material and structural interventions

NICE guideline <number>

Evidence review

June 2019

Draft for Consultation

These evidence reviews were developed by the Public Health Internal Guideline Development team

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Material and structural interventions to prevent or reduce the health impacts of poor indoor air quality at home

Review question

What are the effective material and structural interventions to prevent or reduce the health impacts of poor indoor air quality at home?

Introduction

People spend up to 90% of their lives indoors and 60% of that time at home. Exposure to indoor air pollutants including nitrogen dioxide (NO^2), carbon monoxide (CO), particulate matter (PM), biological agents and volatile organic compounds (VOCs) is widespread. These pollutants are associated with respiratory and other diseases and premature death.

Table 1: PICO table

Field	Content
Population	People in all dwellings
Interventions	Interventions to improve poor indoor air quality for example: • Removing sources of indoor air pollution for example installing cooker hoods, kitchen extractors • Using construction materials and consumer products with low volatile organic compound (VOC) emissions • installing air filtering systems to remove biological agents (for example, dander and dust) and particulate matter, • installing insulation to change the dew point (the temperature at which condensation appears) and prevent mould growth • Retrofitting ventilation units in existing buildings • Maintaining adequate moisture levels (including dehumidifiers) to prevent damp and mould • Material or structural interventions to reduce house dust mites • Making buildings more 'breathable' using vapour-permeable or hygroscopic materials • replacing old heating systems • Use of soft furnishings including flame-retardant and stain-resistant treatments
Comparator(s)/control	Interventions compared to alternative, no repairs, no installation or do nothing
Outcomes	Respiratory health effects • Changes in pulmonary function measured as a reduction in e.g. FEV1, PEF • Respiratory symptoms for example cough, wheeze, phlegm, sore throat, nasal congestion, runny nose, sneezing • Respiratory infection for example Pneumonia, alveolitis, bronchitis • COPD

Field	Content

	• Asthma
	• Allergic diseases for example
	  ○ Allergic asthma
	  ○ Allergic alveolitis
	  ○ Allergic rhinoconjuctivitis
	  ○ Allergic rhinitis
	  ○ Allergic dermatitis
	• Pregnancy related health effects for example
	• Low birthweight, perinatal mortality (still births and deaths in the first week of life)
	• Cardiovascular health effects. For example
	• Ischaemic heart disease, stroke
	• HRQOL

Methods and process

This evidence review was developed using the methods and process described in Developing NICE guidelines: the manual. Methods specific to this review question are described in the review protocol in Appendix B:.

Respiratory conditions were reported differently within and across studies. Due to the myriad of respiratory conditions reported and measures used, the committee agreed that:

- Where 2 or more respiratory conditions are reported, to use the most sensitive outcome. For example, using Forced expiratory volume - 1 second (FEV1) over peak expiratory flow (PEF) or
- Where 2 or more respiratory conditions are reported, to use the one reported as the primary outcome for which the trial was powered. For example, reporting wheeze powered for study over cough

Declarations of interest were recorded according to NICE's 2018 conflicts of interest policy.

Public health evidence

For this review, only randomised controlled trials (RCTs) and cluster RCTs were considered for inclusion.

19418 references were identified from literature searches outlined in Appendix B. An additional 4 references were identified from published systematic reviews and 1,345 references from the rerun of the literature search. 119 papers were ordered in full-text. 9 RCTs (reported in 14 papers) met the inclusion criteria outlined in the review protocol. 105 studies were excluded. See Appendix C for Public health evidence study selection

Included studies

9 RCTs were included for this review. 7 of the RCTs were identified from priority screening and 2 from the Agency for Healthcare Research and Quality (AHRQ) comparative effectiveness review on 'Indoor Allergen Reduction in Management of Asthma'. 4 studies were conducted in the United Kingdom (UK), 2 studies from the United States (US), 1 study from Canada and 2 from New Zealand.

For health outcomes, included studies did not report on COPD, pregnancy related health effects and cardiovascular health effects. For indoor air pollutants, studies did not report on carbon monoxide (CO), and polycyclic aromatic hydrocarbons (PAHs). For subgroups of interest, studies did not report on people on low income, older people, people with disabilities, and pregnant women. See table 2 below for more details on the included studies.

Excluded studies

105 studies were excluded from this review. See Appendix G: for full list of studies excluded with the reasons for exclusion.

Summary of public health studies included in the evidence review

Table 2: Summary of included studies

Study	Population	Intervention	Comparator	Outcome used	Risk of bias
Burr 2007 (UK)	Adults and children with asthma	• Mould removal and positive ventilation	Delayed intervention	Respiratory health	High (concerns over lack of detail on randomisation and unequal loss to follow-up)
Francis 2003 (UK)	Adults with asthma	• HEPA air cleaner + HEPA vacuum cleaner	HEPA vacuum cleaner alone	Respiratory health	Low
Howden-Chapman 2007 (New Zealand)	Adults and children with respiratory problems	• Installation of a retrofit insulation package	Delayed intervention	Respiratory health	High (concerns over lack of details on randomisation and allocation concealment)
Howden-Chapman 2008 (New Zealand)	Children with asthma	• Replacement non-polluting heating	Delayed intervention	Respiratory health	High (concerns over lack of details on randomisation and allocation concealment)
Kovesi 2009 (Canada)	Children without pre-existing condition	• Heat recovery ventilation	Placebo heat recovery ventilation	Respiratory health Rhinitis	Low
Noonan 2017 (US)	Children with asthma	• Improved technology wood burning stove or Functioning air filtration devices	Sham intervention	Respiratory health Quality of life	High (concerns over lack of details on randomisation and allocation concealment)
Park 2017 (US)	Children with asthma and/or allergic rhinitis	• HEPA air purifier	No treatment	Respiratory health	High (concerns over lack of details on randomisation and allocation concealment)
Tan 1996 (UK)	Children and adults with atopic dermatitis	• Impermeable bedcovers + benzyltannate spray + high-filtration vacuum cleaner	Placebo covers, placebo spray (water), and a conventional domestic vacuum cleaner	Atopic dermatitis	Moderate (concerns over attrition rate in placebo group)
Wright 2009 (UK)	Adults with asthma	• Mechanical heat recovery ventilation (MHRV	Placebo ventilation	Asthma Respiratory health Quality of life	Low

See Appendix D for full evidence tables.

Economic evidence

For the review of published cost effectiveness evidence see Evidence reviews for indoor air quality at home: Cost effectiveness outcomes

Economic model

For the results of the economic analysis see Indoor Air Quality at Home Economic Model Report and Community Health Worker Appendix.

Evidence statements

House dust mite (see GRADE profile F.1)

- Moderate quality evidence from 1 RCT on adults and children with atopic dermatitis followed up for 6 months showed a significant reduction in eczema severity score with the use of impermeable mattress and pillow cover, benzyltannate spray and HEPA vacuum cleaner to prevent/reduce house dust mite compared to the control group (n = 48; MD -4.2 95% CI -6.7 to -1.7)
- Low quality evidence from 1 RCT on adults with asthma followed up for 12 months showed no difference in quality of life with the use of MHRV units fitted in the roof space or hallway cupboard to prevent/reduce house dust mite compared to the control group (n = 119; MD -2.83 95% CI -7.82 to 2.16)
- Moderate quality evidence from 1 RCT on adults with asthma followed up for 12 months showed no difference in asthma control (using the asthma control questionnaire) with the use of a mechanical heat recovery ventilation (MHRV) system fitted in the roof space or hallway cupboard (these units extract air continuously from the kitchen and bathroom and deliver pre-warmed air via insulated ducts into the bedroom and living room) to prevent/reduce house dust mite compared to the control group (n = 119; MD -0.25 95% CI -0.57 to 0.08)
- Low quality evidence from 1 RCT on adults with asthma followed up for 12 months showed no difference in respiratory health effect with the use of mechanical heat recovery ventilation (MHRV) units fitted in the roof space or hallway cupboard to prevent/reduce house dust mite compared to the control group (n = 119; MD 1.32 95% CI -2.56 to 5.19)

Particulate matter (see GRADE profile F.2)

- Very low quality evidence from 1 RCT on children with asthma followed up for 12 months showed no difference in quality of life with the use of low emission (according to EPAS standards) wood burning stove to prevent/reduce particulate matter compared to the control group (n = 45; MD 0.18 95% CI -0.33 to 0.69)
- Low quality evidence from 1 RCT on children with asthma followed up for 12 months showed no difference in quality of life with the use of air filtration devices to prevent/reduce particulate matter compared to the control group (n = 69; MD - 0.07 95% CI -0.47 to 0.34)
- Low quality evidence from 1 RCT on children with asthma followed up for 12 months showed no difference in respiratory health effect with low-emission (according to EPA standards) wood burning stove to prevent/reduce particulate matter compared to the control group (n = 45; MD 3.6 95% CI -6.8 to 14)
- Very low quality evidence from 1 RCT on children with asthma followed up for 12 months showed no difference in respiratory health effect with the use of air filtration unit placed in the living room and the child’s bedroom to prevent/reduce

particulate matter compared to the control group (n = 69; MD -0.71 95% CI -8.9 to 7.5)

- Moderate quality evidence from 1 RCT on children with asthma and/or allergic rhinitis followed up for 12 weeks showed significant reduction in respiratory health effect with the use of HEPA air purifier placed in living rooms and bedrooms to prevent/reduce particulate matter compared to the control group (n = 17; MD -3.10 95% CI -5.12 to -1.08)

Gases (NO2, CO2) (see GRADE profile F.3)

- Low quality evidence from 1 RCT on children with asthma followed up for 12 months showed no difference in respiratory health effect with the use of replacement heaters (heat pump, wood pellet burner, or flued gas) to prevent/reduce NO2 compared to the control group (n = 349; OR 0.71 95% CI 0.45 to 1.11; number of events not reported)
- High quality evidence from 1 RCT on children without any pre-existing conditions followed up for 6 months showed no difference in respiratory health effect (wheezing) with the use of MHRV to prevent/reduce CO2 compared to the control group (n = 68; OR 0.00 95% CI 0.0074 to 0.36)
- Low quality evidence from 1 RCT on children without pre-existing conditions followed up for 6 months showed no difference in rhinitis with the use of MHRV to prevent/reduce CO2 compared to the control group (n = 68; OR 0.60 95% CI 0.083 to 3.86; number of events not reported)

Mould (see GRADE profile F.4)

- Moderate quality evidence from 1 RCT on adults with asthma followed up for 12 months showed no difference in respiratory health effect with the use of MHRV units installed in the loft to prevent/reduce mould compared to the control group (n = 164; MD 0.46 95% CI -01.58 to 2.50)
- Moderate quality evidence from 1 RCT on adults and children with respiratory symptoms followed up 24 months showed significant reduction in respiratory health effect with the Installation of a retrofit insulation package (including ceiling insulation, draught stopping around windows and doors, and fitting sisalated paper beneath floor joists and a polythene moisture barrier on the ground) to prevent/reduce mould compared to the control group (n = 2775; OR 0.62 95% CI 0.53 to 0.73)

Pet dander (see GRADE profile F.5)

- Moderate quality evidence from 1 RCT on adults and children with respiratory symptoms followed up 24 months showed no difference in respiratory health effect with the use of HEPA cleaner and vacuum to prevent/reduce pet dander compared to the control group (n = 30; MD 0.25 higher 95% CI -0.38 to 0.88)

Recommendations

Research recommendations

What is the effectiveness and cost-effectiveness of interventions to improve indoor air quality at home in people without pre-existing health conditions? See PICO in L.1.1

How can damp and mould be identified and fixed? How can a recurrence of damp be prevented? See PICO in L.1.2

Rationale and impact

Link to be added

The committee's discussion of the evidence

Interpreting the evidence `

The outcomes that matter most

The committee considered all outcomes to be of equal importance. Indoor air quality at home can be affected by various pollutants, including gases (for example NO2, carbon monoxide), (total) volatile organic compounds ([T] VOCs), particulate matter (PM) from for example open solid-fuel fires, or cooking, polycyclic aromatic hydrocarbons (PAHs for example, naphthalene and benzo[a]pyrene) and biological agents such as mould and pet dander. Emissions in the home increase personal exposure to pollutants and contribute significantly to overall national emissions. Exposure to these different pollutants are associated with negative health outcomes especially in the case of vulnerable groups for example people with pre-existing health conditions. Poor indoor air quality is known to exacerbate health effects in these vulnerable groups compared to the general population for example exacerbation of wheeze and/or cough in people with asthma. Other vulnerable groups considered include the very young, the very old, people who are pregnant, people who live in poor quality housing, people on low incomes, people with disabilities and people who spend longer than average time at home. These groups of people are likely to experience a higher exposure to poor indoor air quality at home leading to poor health outcomes

The quality of the evidence

The committee noted there was no evidence on many of the interventions of interest. These included the

- removal of hazardous building materials,
- the use of construction materials and consumer products with low VOC emissions.
- Installing extractor fans.
- Reducing high humidity levels (using dehumidifiers)
- Making the building more airtight (for example, by insulating, draught proofing or installing double glazing).
- Making buildings more 'breathable' using vapour-permeable or hygroscopic materials
- Use of soft furnishings and other interior design factors, including flame-retardant and stain-resistant treatments.

The committee noted evidence gaps in relation to people with low income, older people, people with disabilities and pregnant women. There was also limited evidence on children and young people. The majority of studies included people with asthma.

The committee also noted that there was no evidence for some outcomes of interest such as cardiovascular health effects, chronic obstructive pulmonary disease (COPD) or pregnancy related health effects.

The committee acknowledged the uncertainty in evidence base and noted that this might be due to differences in populations, in terms of different ages and risk profiles and the myriad of ways of reporting on the same outcome.

The committee acknowledged methodological limitations as regards the reporting of study design and conduct that were identified during the risk of bias assessment. One of such limitations is the lack of blinding reported in included studies. The committee highlighted that blinding of participants and study personnel may be difficult or impossible to achieve due to the nature of interventions delivered. For experimental and pragmatic reasons, the existence of a lack of blinding as a methodological limitation was accepted by the committee. The committee agreed not to downgrade in the GRADE assessment for these interventions where blinding is a consideration.

Another limitation the committee considered was the use of subjective measures (for example using self-reported questionnaires) rather than objective measure for outcomes and how this might influence their understanding of the evidence base. The committee was also concerned with most of the evidence reporting on people with pre-existing conditions and they noted that this may result in over reporting of health symptoms. For example, people with asthma, because of concerns about exacerbations linked to poor indoor air quality may seek medical advice to a greater degree than people without asthma. This may lead to wheeze or other respiratory health effects being over reported while on the other side of the spectrum, a healthy population might not seek medical advice for these symptoms. The committee considered that the outcomes reported in the included studies were short term outcomes that are an important indicator of the effectiveness of the intervention, However, the committee also had concerns over the lack of longer-term outcome data.

The committee noted that 5 of the 9 included studies were conducted outside the UK. However, they agreed that the climate conditions and regulatory environments were similar to the UK. In addition, the committee considered that the interventions examined in these studies were consistent with current practice in the UK and so had no concerns about the generalisability of the evidence base.

Benefits and harms

The committee noted that benefits were observed with a multicomponent intervention (Impermeable mattress and pillow cover, benzyltannate spray and HEPA vacuum cleaner) from one study (Tan 1996) in terms of reducing eczema severity in children and adults with atopic dermatitis though the committee found it difficult to determine the effectiveness of each component. Findings for replacement heaters and MHRV units from 2 studies (Howden-Chapman 2007 & Howden-Chapman 2008) showed a benefit in terms of respiratory health effects on children with asthma as did the use of HEPA filters in children with asthma and/or allergic rhinitis. Similarly retrofitting and improving ventilation systems (such as mechanical ventilation systems or openable windows) showed a benefit in terms of respiratory health effects and quality of life respectively.

There were discussions around how the evidence reported did not entirely reflect the committee's collective experience. It was noted that many of these interventions will logically reduce the levels of a pollutant, but this was not translated in health benefits in the studies.

The committee cited examples where interventions to prevent NO^2, for example switching from gas cookers to electric cookers, will remove the source of NO^2 in the home. Also, interventions to reduce indoor particulate matter (for example using cooker hoods when cooking) have been shown to be effective in real life and that the benefits outweigh unintended harms, such as the noise from cooker hood.

Renovating homes without improving ventilation may negatively affect the health of the people who live in them (see evidence review 3.3). The committee noted this evidence and agreed that adequate ventilation was essential to maintaining good indoor air quality.

Cost effectiveness and resource use

The committee noted the paucity of health economic literature on structural and material interventions. It also noted that the studies which had been identified were only partially applicable and of low quality. Even so, the committee were mindful that this literature suggests that ventilation systems, carbon filters used alongside ventilation systems, home modifications and home modifications combined with education interventions could be cost effective and in certain circumstances cost saving. The economic model also suggested that interventions to reduce exposure to indoor air pollution could be cost saving. However, the committee are aware that some interventions may have little or no cost (e.g. opening a window) whereas others could be costly (e.g. installing a ventilation system). It was particularly noteworthy therefore that the main driver of the cost savings was the excess risk profile of dwellings which is a combination of physical (building) risk and personal baseline risk. For example, a dwelling with a low risk function and an intervention that is effective in reducing the prevalence of asthma (by 5%) is unlikely to be cost-saving unless the cost of implementation per dwelling is £50 or lower whereas, for an extreme risk dwelling the cost-saving threshold rises to £150 at a 5% effectiveness. A key limitation of the model is that there were no data on the explicit link between indoor air quality and health outcomes in general, and specifically for any of the interventions of interest to the committee. Some identified benefits could not be quantified for example, the benefits that an intervention may bring to someone with comorbidities, suggesting that the overall benefits are likely to have been underestimated. So, the committee concluded that interventions could offer good value for money in certain scenarios.

Other factors the committee took into account

The committee highlighted that there are multiple factors to consider once poor air quality at home has been identified. These factors range from the age of the building, to the source of the pollutant, to the air exchange rate and air-flow through the dwelling. For example, if concerns were raised about levels of NO^2 from a gas cooker the intervention options should include,

- installing and using an extractor fan
- replacing the gas cooker with an electric one
- opening the windows (where possible) while using gas cookers.

Each of these options may or may not be possible depending on the context and the individual building characteristics. As it may not be possible to install an extractor fan to the outside due to the nature of the building, it may not be possible for the tenant in a rented apartment to replace a gas cooker and opening a kitchen window may not be practical for either security or outdoor air pollution reasons. To this end, the committee agreed that design strategies need to ensure pollutants can be diluted by ventilation (for example, by using extractor fans or openable windows). These strategies should take into account the specific characteristics of the building (such as location, building type, orientation and aspect) that may affect ventilation provision, as well as regulations that need to be are adhered to.

While there was no evidence for the effectiveness of low-emission materials, the committee based on their collective experience agreed that these would be safer than high-emission products. The committee highlighted the importance of when low emission materials are specified, substituting building materials with low emission products, whether renovating or working on a new-build. The committee also considered it equally important that manufacturers' guidance for use of these materials and products are followed.

While there was also no evidence on some interventions, for example extractor fans, the committee agreed that cooking using a gas stove was a source a pollution from NO_2 (see evidence review 1).The committee thus considered it sensible that any measure that helps reduce exposure, for example installing and using extractor fans, to this pollutant even if there was no interventional studies to demonstrate effectiveness.

The committee highlighted that the standards for material or structural choice and requirements for effective ventilation are critical parts of the design of retrofits. In addition, the design should take into account the whole building performance and use emerging standards for domestic retrofits. The committee also agreed that it was essential to follow manufactures instructions on the appropriate installation and use of ventilation systems.

The committee noted that compliance checking and verification of how systems perform once installed is needed to ensure that regulations and standards are met. In practice this building control teams or inspector use various regulations or standards to assess compliance. For example, building regulations are generally used to enforce standards in new housing. Other local standards may be used for existing homes, for example landlord legislation or standards on repairs and property condition. The committee were aware of enforcement powers that local authorities can use to ensure compliance with regulations. (See the Planning Portal's Failure to comply with the building regulations.)

Based on their experience, the committee also agreed that if the source of an indoor air pollutant cannot be removed, design strategies need to ensure the pollutant can be diluted by ventilation. These should take into account the specific characteristics of the building (such as location, building type, orientation and aspect) that may affect ventilation provision, as well as regulations that need are adhered to.

The committee stressed that identifying the source of the pollutant will help in identifying the type of intervention to be offered. For example, changing a leaky or damaged drain pipe to prevent damp and mould or improving the ventilation system in the home to reduce humidity levels. This led to the committee drafting recommendations giving advice on how to deal with the source of pollutants and if this is not possible how to dilute it using ventilation.

Architects and designers are involved in the design of new builds from the early stages. The committee agreed that this puts them in an ideal position to take an overview of the whole building performance to ensure adequate ventilation, mechanical or otherwise, is included in the design and is considered in relation to other building factors such as building type and location. Design should also consider how heating and ventilation should be operated and maintained and how this will be communicated to building occupants and owners.

In addition, the committee agreed that housing and fuel costs can reduce choices for those on a low income. For example, they may not be able to afford to heat all the rooms to a constant temperature, or may only use heating intermittently (for example, when expecting a home visit). Both approaches can cause damp. The committee referred to NICE's guideline on excess winter deaths and illness and the health risks associated with cold homes for more details.

The committee acknowledged that the outcomes presented were mostly short term health outcomes and suggested that long term outcomes might be difficult to assess in randomised control studies as it requires time and resources. The committee then drafted research recommendations focussing on longer term health outcomes.

1 # Appendices

2 # Appendix A: Review protocol

3 Review protocol for material and structural interventions

Field	Content
Review question	What are the effective material and structural interventions to prevent or reduce the health impacts of poor indoor air quality at home?
Type of review question	Intervention and qualitative
Objective of the review	To identify effective material and structural interventions for preventing or reducing the health impacts of poor indoor air quality at home
Eligibility criteria – population/disease/condition/issue/domain	People in all dwellings
Eligibility criteria – interventions	Interventions to improve poor indoor air quality for example: Removing sources of indoor air pollution for example installing cooker hoods, kitchen extractors Using construction materials and consumer products with low volatile organic compound (VOC) emissions installing air filtering systems to remove biological agents (for example, dander and dust) and particulate matter, installing insulation to change the dew point (the temperature at which condensation appears) and prevent mould growth Retrofitting ventilation units in existing buildings Maintaining adequate moisture levels (including dehumidifiers) to prevent damp and mould Material or structural interventions to reduce house dust mites Making buildings more 'breathable' using vapour-permeable or hygroscopic materials replacing old heating systems Use of soft furnishings including flame-retardant and stain-resistant treatments
Eligibility criteria – comparator(s)/control	Interventions compared to alternative, no repairs, no installation or do nothing
Outcomes and prioritisation	Respiratory health effects Changes in pulmonary function measured as a reduction in e.g. FEV1, PEF Respiratory symptoms for example cough, wheeze, phlegm, sore throat, nasal congestion, runny nose, sneezing Respiratory infection for example Pneumonia, alveolitis, bronchitis COPD Asthma Allergic diseases for example Allergic asthma Allergic alveolitis

Field	Content
	Allergic rhinoconjuctivitis Allergic rhinitis Allergic dermatitis Pregnancy related health effects for example Low birthweight, perinatal mortality (still births and deaths in the first week of life) Cardiovascular health effects. For example Ischaemic heart disease, stroke HRQOL
Eligibility criteria – study design	Studies of effectiveness and cost-effectiveness Inclusion: RCTs Cluster RCTs UK based qualitative studies Economic studies: Cost-utility (cost per QALY) Cost benefit (i.e. net benefit) Cost-effectiveness (Cost per unit of effect) Cost minimization Cost-consequence Exclusion: Systematic reviews will not be included but may be used as a source of primary studies Cross-sectional and other surveys Case control studies
Other inclusion/exclusion criteria	Inclusion: English language only Published peer-reviewed studies only Studies conducted in developed economies similar to the UK Studies conducted from 1970 onwards Exclusion: Conference abstract, letter, opinion piece, review articles
Proposed sensitivity/sub-group analysis, or meta-regression	Where evidence allows, pre-specified sub-group analysis will be conducted to include those at increased risk of poor indoor air quality: Subgroup People on low income Older people People with disabilities Pregnant women Children and young people People with conditions associated with or exacerbated by indoor air pollution, such as stroke, heart disease, allergic disease and asthma
Selection process – duplicate	A 10% random sample of abstracts will be duplicate screened as a reliability check. Any disagreement will be resolved by

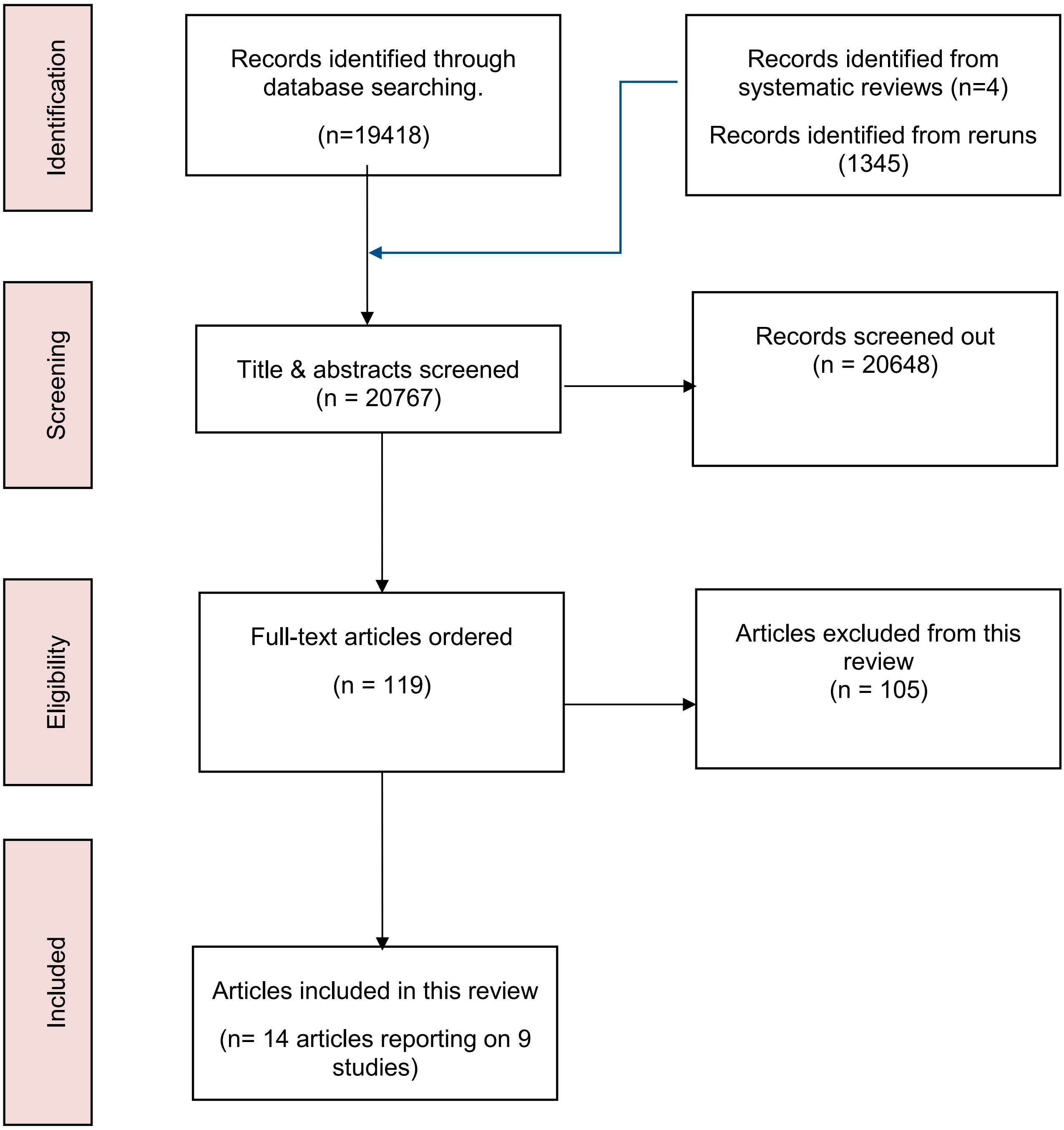
Field	Content
screening/selection/analysis	discussion, or if necessary, a third independent reviewer. If the initial level of agreement is below 90%, a second round of screening will be considered. A 10% random sample of data extraction and critical appraisal will be checked by a second reviewer. Any disagreements will be resolved by the two reviewers, and escalated to a third reviewer if agreement cannot be reached. Only 10% of the search results will be checked as this is an intervention and qualitative review and there is confidence that RCTs, controlled studies or related qualitative studies are unlikely to be missed at the sifting stage. The inclusion list will be double checked with PHAC to ensure no studies are excluded inappropriately
Information sources – databases	A systematic search of relevant databases will be carried out to identify relevant studies and evidence. Appropriate limits will be applied. Database functionality will be used, where available, to exclude: Non-English language papers Animal studies Editorials, letters, news items and commentaries Conference abstracts and posters Theses and dissertations Duplicates Websites will be browsed or searched to focus on relevant evidence. The bibliographies of relevant reports and findings may also be used to capture evidence. The following databases will be searched: MEDLINE and MEDLINE in Process (OVID) Embase (OVID) Health Management Information Consortium (HMIC) (OVID) Social Policy and Practice (OVID) CENTRAL (Wiley) Cochrane Database of Systematic Reviews (Wiley) DARE (Wiley) Greenfile (EBSCO) NHS EED (legacy database) (Wiley) EconLit (OVID) OpenGrey Web of Science The following websites will be searched: Google and Google scholar (with appropriate limits and looking specifically for reports or evaluations of interventions related to indoor air quality)

Field	Content
Data management (software)	Where feasible data management will be undertaken using EPPI-reviewer software. Pairwise meta-analyses will be performed using Cochrane Review Manager (RevMan5). Where appropriate, qualitative data will be summarised using an appropriate qualitative synthesis approach, for example, narrative synthesis.
Methods for assessing bias at outcome/study level	Standard study checklists will be used to critically appraise individual studies. For details please see section 6.2 of Developing NICE guidelines: the manual For intervention studies the Cochrane Risk of Bias 2.0 tool will be used and for qualitative studies, the Cochrane qualitative checklist will be used. The Grading of Recommendations Assessment, Development and Evaluation (short GRADE) developed by the GRADE working group http://www.gradeworkinggroup.org/ will be used to assess the quality of evidence across outcomes. Where necessary, GRADE will be modified to meet the needs of the review question. GRADE-CERQUAL will be used for qualitative findings.
Criteria for quantitative synthesis	Data from eligible studies will be extracted for inclusion in evidence tables. For details please see section 6.4 of Developing NICE guidelines: the manual
Methods of quantitative analysis – combining studies and exploring (in)consistency	Data from eligible studies will be meta-analysed (combined) if studies are judged to be similar enough in terms of population, interventions, outcomes, study design or risk of bias. Where appropriate, inconsistency will be explored by conducting subgroup analyses. Where appropriate, inconsistency will be incorporated by performing random-effect analyses If the studies are found to be too heterogeneous to be pooled statistically, a narrative synthesis will be conducted.
Meta-bias assessment – publication bias, selective reporting bias	For details please see section 6.2 of Developing NICE guidelines: the manual.
Confidence in cumulative evidence	For details please see sections 6.4 and 9.1 of Developing NICE guidelines: the manual

Appendix B: Literature search strategies

Please see search strategies here

Appendix C: Public health evidence study selection



Appendix D: Public health evidence tables

D.1 House dust mite

Tan 1996

Bibliographic reference	Tan B B, Weald D, Strickland I, and Friedmann P S (1996) Double-blind controlled trial of effect of house dust-mite allergen avoidance on atopic dermatitis. Lancet (London, and England) 347(8993), 15-8		
Registration	Not reported		
Study type	RCT		
Study dates	Study participants recruited between November 1993 and April 1994		
Objective	To determine if atopic dermatitis improves with a reduction in house dust mite allergen in the home		
Country/ Setting	UK/setting not reported in the study		
Number of participants	60		
Participant characteristics	Demographic characteristics	House dust mite avoidance	Placebo house dust mite avoidance
	Age	Not reported	Not reported
	Sex	Not reported	Not reported
	Race	Not reported	Not reported
	Homeownership	Not reported	Not reported
	Geographic environment	Not reported	Not reported
	Clinical factors (baseline)	Not reported	Not reported
	HDM Sensitization, (serum IgE) mean (SE):	Not reported	Not reported
	Comorbidity:	Not reported	Not reported
	Atopic rhinitis	Not reported	Not reported
	Atopic conjunctivitis	Not reported	Not reported
	Atopic dermatitis	30 (100%)	30 (100%)
Exposure	House dust mite		
Inclusion criteria	People with atopic dermatitis aged between 7 and 65 years		
Exclusion criteria	Pet ownership		
Intervention	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	15	House dust mite avoidance
	Rationale/theory/Goal		NA

Bibliographic reference	Tan B B, Weald D, Strickland I, and Friedmann P S (1996) Double-blind controlled trial of effect of house dust-mite allergen avoidance on atopic dermatitis. Lancet (London, and England) 347(8993), 15-8		
	Materials used	15	Goretex bedcovers), benzyltannate spray and a high-filtration vacuum cleaner
	Procedures used		NA
	Provider		NA
	Method of delivery		NA
	Location		Home
	Duration		NA
	Intensity		NA
	Tailoring/adaptation		NA
	Modifications		NA
	Planned treatment fidelity		NA
	Actual treatment fidelity		NA
	Other details		NA
Comparison	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name		Placebo house dust mite avoidance
	Rationale/theory/Goal		NA
	Materials used		Cotton covers, placebo spray (water), and a conventional domestic vacuum cleaner
	Procedures used		NA
	Provider		NA
	Method of delivery		NA
	Location	15	Home
	Duration		NA
	Intensity		NA
	Tailoring/adaptation		NA
	Modifications		NA
	Planned treatment fidelity		NA
	Actual treatment fidelity		NA
	Other details		NA
	Other details	-	NA
Follow up	6 months		
Study Methods	Method of randomisation	Not reported	
	Method of allocation concealment	Trained nurse applied interventions	

Bibliographic reference	Tan B B, Weald D, Strickland I, and Friedmann P S (1996) Double-blind controlled trial of effect of house dust-mite allergen avoidance on atopic dermatitis. Lancet (London, and England) 347(8993), 15-8	
	Statistical method(s) used to analyse data	Continuous outcomes assessed by analysis of covariance with initial scores and
	Unit of allocation	Individual
	Unit of analysis	Individual
	Attrition	20 %
Outcomes measures and effect size.	Primary outcomes	
	Global eczema severity using a named scale (SASSAD) Severity core – reported as mean difference (range)	-4.2 (1.7, 6.7))

Risk of bias (ROB)	Outcome	Judgement	Comments
	Random sequence generation	Unclear	No details provided
	Allocation concealment	Low	Individual not associated with assessment applied the interventions
	Blinding of participants and personnel	Low	Double-blinding for participants and assessors
	Blinding of outcome assessment	Low	Double-blinding for participants and assessors
	Incomplete outcome data	High	Unbalanced dropout rate 2 (6.7%) in intervention group vs 10 (33.3.%) in control group
	Selective reporting	Low	All pre-specified outcomes reported
	Other sources of bias	Low	No concerns
Overall ROB	Moderate		
Source of funding	National Eczema Society		
Comments	Authors concluded that the activity of atopic dermatitis can be greatly reduced by effective HDM avoidance. Methods to identify individuals who will benefit most from such measures are needed		
Additional references	Friedmann P S, and Tan B B. 1998. "Mite elimination--clinical effect on eczema". Allergy 53(48 Suppl):97-100		

Wright 2009

Bibliographic reference	**Wright GR, Howieson S, McSharry C, et al. Effect of improved home ventilation on asthma control and house dust mite allergen levels. Allergy. 2009 Nov;64(11):1671-80**
Registration	NCT00148096

Bibliographic reference	Wright GR, Howieson S, McSharry C, et al. Effect of improved home ventilation on asthma control and house dust mite allergen levels. Allergy. 2009 Nov;64(11):1671-80		
Study type	RCT		
Study dates	Published 2009		
Objective	To determine if domestic mechanical heat recovery ventilation, in addition to allergen avoidance measures, can improve asthma control of those sensitive to house dust mite allergen,		
Country/ Setting	UK/home		
Number of participants	119		
Participant characteristics	Demographic characteristics	Domestic mechanical heat recovery ventilation (MHRV)	Placebo ventilation system
	Age, mean (SD)	41.6 (9.6)	42.3 (10.7)
	% male	38.7% (not reported by groups)	
	Race		
	Caucasian	97.5% (not reported by groups)	
	Asian	2.5% (not reported by groups)	
	Homeownership	Not reported in the study	
	Geographic environment	Not reported in the study	
	Clinical factors (baseline)		
	Sensitization: Serum HDM IgE antibody, median (IQR)	5.7 (1.6 to 13.1)	6.1 (2.3 to 15.2)
	Asthma severity: Asthma control score (0–6), median (IQR)	1.57 (1.18 to 2.54)	1.86 (1.14 to 2.71)
	Baseline spirometry		
	Pre-bronchodilator FEV1 % predicted, mean (SD):	83.7 (18.0)	82.7 (17.7)
	Post-bronchodilator FEV1 % predicted, mean (SD):	86.6 (18.1)	89.5 (15.6)
	FVC % predicted- Pre-bronchodilator, mean (SD):	93.5 (13.6)	95.0 (15.4)
	Mean duration of asthma, year, median (IQR):	21.0 (9.2 to 30.7)	16.0 (9.0 to 25.0)
	Comorbidity, n:		
	Hay fever/nasal allergy	44	47
	Eczema	15	14
	Hypertension	5	8
	Angina	2	3
	Diabetes	3	2
	Prior stroke	1	2

Bibliographic reference	Wright GR, Howieson S, McSharry C, et al. Effect of improved home ventilation on asthma control and house dust mite allergen levels. Allergy. 2009 Nov;64(11):1671-80		
	Other respiratory:	0	1
	Prior myocardial infarction:	0	1
	Current smoker, n:	12	17
Exposure	House dust mite		
Inclusion criteria	Aged between 16 to 60 years Had asthma for more than one year On regular inhaled corticosteroids and had daily symptoms.		
Exclusion criteria	If they were likely to move house or had a pet that provoked their symptoms.		
Intervention	TIDieR Checklist criteria	Paper/Location	Details
	Study details extracted from the Agency for Healthcare Research and Quality (AHRQ) comparative effectiveness review on 'Indoor Allergen Reduction in Management of Asthma 2018		
	Brief Name	-	Domestic mechanical heat recovery ventilation (MHRV)
	Rationale/theory/Goal	-	NA
	Materials used	-	NA
	Procedures used	-	NA
	Provider	-	NA
	Method of delivery	-	NA
	Location	-	NA
	Duration	-	NA
	Intensity	-	NA
	Tailoring/adaptation	-	NA
	Modifications	-	NA
	Planned treatment fidelity	-	NA
	Actual treatment fidelity	-	NA
	Other details	-	NA
Comparison	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	-	Placebo ventilation system. In the placebo arm, low-level electric motors were set to 'on' but were not connected

Bibliographic reference	**Wright GR, Howieson S, McSharry C, et al. Effect of improved home ventilation on asthma control and house dust mite allergen levels. Allergy. 2009 Nov;64(11):1671-80**		
			to the ventilation fans
	Rationale/theory/Goal	-	NA
	Materials used	-	NA
	Procedures used	-	NA
	Provider	-	NA
	Method of delivery	-	NA
	Location	-	NA
	Duration	-	NA
	Intensity	-	NA
	Tailoring/adaptation	-	NA
	Modifications	-	NA
	Planned treatment fidelity	-	NA
	Actual treatment fidelity	-	NA
	Other details	-	NA
Follow up	12 months		
Study Methods	Method of randomisation	Sequential blocks of four using an automated telephone answering system	
	Method of allocation concealment	activation device concealed from patient and research team	
	Statistical method(s) used to analyse data	The main analyses were carried out with ANCOVA models adjusted for baseline severity. The analyses were firstly carried out on an intention to treat basis. The primary and secondary endpoints were repeated for the 'per protocol' set. Binary endpoints such as hospitalizations were compared by odds-ratios, the attendant 95% confidence interval and tested by Mantel-Haenszel chi-squared test.	
	Unit of allocation	Individual	
	Unit of analysis	Individual	
	Attrition	15% attrition and intent-to-treat analysis	
Outcomes measures and effect size.	Primary outcomes		
		Domestic mechanical heat recovery ventilation (MHRV)	Placebo ventilation system
	Asthma (asthma control questionnaires)	Adjusted mean difference between groups (95% CI): -0.25 (-0.57 to 0.08); p=not significant	
	Pulmonary physiology		

Bibliographic reference	**Wright GR, Howieson S, McSharry C, et al. Effect of improved home ventilation on asthma control and house dust mite allergen levels. Allergy. 2009 Nov;64(11):1671-80**		
	FEV1, % predicted (mean ± SD)		Adjusted mean difference between groups (95%CI) 1.32 (-2.56 to 5.19)
	Morning PEFR, l/min		adjusted difference between groups (95% CI): 13.59 (-2.66 to 29.85); p=not significant
	Evening PEFR, l/min		adjusted difference between groups (95% CI): 24.56 (8.97 to 40.15); p=0.002; favours MHRV
	Quality of life		
	SGRQ (mean ± SD)		Adjusted mean difference between groups (95%CI) -2.83 (-7.82 to 2.16)
Risk of bias (ROB)	Outcome	Judgement	Comments
	Random sequence generation	Low	Sequential blocks of four using an automated telephone answering system
	Allocation concealment	Low	
	Blinding of participants and personnel	Low	Patients blinded
	Blinding of outcome assessment	Low	Outcomes assessors blinded
	Incomplete outcome data	Low	Placebo used; 15% attrition and intent-to-treat analysis
	Selective reporting	Low	No concerns over reporting
	Other sources of bias	Low	No concerns
Overall ROB	Low		
Source of funding	Chief Scientist's Office of the Scottish Executive Greater Glasgow Primary Care NHS Trust		
Comments	No		

D.2 Particulate matter

Noonan 2017

Bibliographic reference	**Noonan CW, Semmens EO, Smith P et.al. 2017. "Randomized Trial of Interventions to Improve Childhood Asthma in Homes with Wood-burning Stoves". Environmental health perspectives 125(9):097010.**
Registration	NCT00807183
Study type	Randomised controlled study

Bibliographic reference	Noonan CW, Semmens EO, Smith P et.al. 2017. "Randomized Trial of Interventions to Improve Childhood Asthma in Homes with Wood-burning Stoves". Environmental health perspectives 125(9):097010.			
Study dates	December 2008 to January 2015			
Objective	To test the hypothesis that (a) improved-technology wood-burning stoves or (b) air-filtration units would result in improvements, relative to placebo, in asthma measures among children in participating homes.			
Country/ Setting	United States			
Number of participants	115			
Participant characteristics	Demographic characteristics	Woodstove change out (n=22)	Air filter (n =46)	Placebo (n=46)
	Age (years) Mean (SD)	12.3(3.1)	12.7(3.3)	12.2(2.5)
	Sex (female)	10(45.5)	25(54.5)	20(43.5)
	Ethnicity			
	American Indian/Alaskan Native	0(0.0)	4(9.8)	0(0.0)
	White	16 (76.2)	32 (78.1)	40 (88.9)
	Other	5(23.8)	5(12.2)	5(11.1)
	Socio-economic status (education)			
	Household post-secondary education	15 (75)	29(74)	31(69)
	Building characteristics	Not reported	Not reported	Not reported
	Existing condition			
	Asthma Severity	20(90.9)	41(89.1)	40(87.0)
Exposure	Particulate matter (PM)			
Inclusion criteria	• Children with asthma • Age 6–18 years • Residing in a non-tobacco-smoking household that used an older-model wood stove as their primary source of heating			
Exclusion criteria	• Not reported			
Intervention	**TIDieR Checklist criteria**	**Paper/Location**	**Details**	
	Brief Name	P1	Improving childhood asthma in homes with wood-burning stoves	
	Rationale/theory/Goal	P2	Investigate the impact improved-technology wood-burning stoves or air-filtration units on asthma among	

Bibliographic reference	Noonan CW, Semmens EO, Smith P et.al. 2017. "Randomized Trial of Interventions to Improve Childhood Asthma in Homes with Wood-burning Stoves". Environmental health perspectives 125(9):097010.		
			children in participating homes
	Materials used	P2	Woodstove change out Air filter
	Procedures used	P2	The woodstove-intervention group received improved-technology wood burning appliances (EPA-certified woodstoves) Air-filter group received functioning air-filtration devices
	Provider	-	Not applicable
	Method of delivery	-	Not applicable
	Location	P2	Intervention delivered at home
	Duration	P2	5 years
	Intensity	-	Not applicable
	Tailoring/adaptation	-	Not applicable
	Modifications	-	Not applicable
	Planned treatment fidelity	-	Not applicable
	Actual treatment fidelity	-	Not applicable
	Other details	-	None
Comparison	**TIDieR Checklist criteria**	**Paper/Location**	**Details**
	Brief Name	P1	Improving childhood asthma in homes with wood-burning stoves
	Rationale/theory/Goal	P2	Investigate the impact improved-technology wood-burning stoves or air-filtration units on asthma among children in participating homes
	Materials used	P2	Sham air-filtration devices
	Procedures used	-	Not applicable
	Provider	-	Not applicable
	Method of delivery	-	Not applicable
	Location	-	Intervention delivered at home
	Duration	P2	5 years
	Intensity	-	Not applicable
	Tailoring/adaptation	-	Not applicable

Bibliographic reference	**Noonan CW, Semmens EO, Smith P et.al. 2017. "Randomized Trial of Interventions to Improve Childhood Asthma in Homes with Wood-burning Stoves". Environmental health perspectives 125(9):097010.**			
	Modifications	-	Not applicable	
	Planned treatment fidelity	-	Not applicable	
	Actual treatment fidelity	-	Not applicable	
	Other details	-	None	
Follow up	12 months			
Study Methods	**Method of randomisation**	Not reported		
	Method of allocation concealment	Not reported		
	Statistical method(s) used to analyse data	Linear mixed effects model that included fixed effects for age and gender. Final model included random effect only for the intercept		
	Unit of allocation	Individual		
	Unit of analysis	Individual		
	Attrition	Number of participants completing the study: 98	Reasons for not completing the study: not reported	
Outcomes measures and effect size.	Post intervention mean changes (95% confidence interval [CI]) relative to placebo adjusted for age and gender (n= 114 participants)			
	Health outcome	Placebo	Woodstove change out	Air filter
	Paediatric Asthma Quality of Life Questionnaire (PAQLQ) scores	0.29 (0.01,0.58)	0.18 (−0:33, 0.69)	−0:07 (−0:47, 0.34)
	Evening FEV1 % predicted	−3:0 (−8:7, 2.6)	2.9 (−7:3, 13)	0.24 (−7:8, 8.3)
	Morning FEV1 % predicted	−2:6 (−8:4, 3.1)	3.6 (−6:8, 14)	−0:71 (−8:9, 7.5)
	Evening PEF % predicted	−7:0 (−12, −1:7)	7.1 (−2:3, 16)	2.4 (−5:0, 9.9)
	Morning PEF % predicted	−6:7 (−12, −1:4)	7.8 (−1:6, 17)	3.4 (−4:1, 11)
Risk of bias (ROB)	**Outcome**	**Judgement**	**Comments**	
	Random sequence generation	High	Not reported	
	Allocation concealment	High	Not reported	
	Blinding of participants and personnel	Unclear	Blinding was not possible for the homes receiving the wood stove intervention	
	Blinding of outcome assessment	Unclear	Field staff responsible for collecting exposure and health data were not blinded	

Bibliographic reference	**Noonan CW, Semmens EO, Smith P et.al. 2017. "Randomized Trial of Interventions to Improve Childhood Asthma in Homes with Wood-burning Stoves". Environmental health perspectives 125(9):097010.**		
	Incomplete outcome data	Low	14% total loss to follow up
	Selective reporting	Low	Pre-specified outcomes reported in analysis
	Other sources of bias	None	None
Overall ROB	High risk		
Source of funding	Study was funded by the National Institutes of Health/National Institute of Environmental Health Sciences (NIH/NIEHS) 1R01ES016336-01and3R01ES016336-02S1. Additional support was provided by NIGMS (1U54GM104944 and P30GM103338) and NICHD (1UG1HD090902).		
Comments			
Additional references	Noonan Curtis W, and Ward Tony J. 2012. "Asthma randomized trial of indoor wood smoke (ARTIS): rationale and methods". Contemporary clinical trials 33(5):1080-7. Ward Tony J, Semmens Erin O, Weiler Emily, Harrar Solomon, and Noonan Curtis W. 2017. "Efficacy of interventions targeting household air pollution from residential wood stoves". Journal of exposure science & environmental epidemiology 27(1):64-71.		

Park 2017

Bibliographic reference	Park H K, Cheng K C, Tetteh A O et.al. 2017. "Effectiveness of air purifier on health outcomes and indoor particles in homes of children with allergic diseases in Fresno, California: A pilot study". Journal of Asthma 54(4):341-346.		
Registration	Not reported		
Study type	Randomised controlled study		
Study dates	April 2015 until July 2015		
Objective	To examine whether the use of air purifiers reduces the levels of PM2.5 in a highly polluted city P341		
Country/ Setting	United States		
Number of participants	16		
Participant characteristics	Demographic characteristics	Active (n = 9)	Control (n = 8)
		n (%)	n (%)
	Age Mean (± SEM)	10.20 (±0.98)	14.40 (±2.50)
	Sex (male)	5 (55.5)	3 (37.5)
	Ethnicity	Not reported	Not reported
	Socio-economic status (education)	Not reported	Not reported
	Building characteristics	Not reported	Not reported
	Existing condition		
	Asthma only	3 (33.3)	5 (62.5)
	Allergic rhinitis	3 (33.3)	1 (12.5)

Bibliographic reference	Park H K, Cheng K C, Tetteh A O et.al. 2017. "Effectiveness of air purifier on health outcomes and indoor particles in homes of children with allergic diseases in Fresno, California: A pilot study". Journal of Asthma 54(4):341-346.		
	Asthma with allergic rhinitis	3 (33.3)	2 (25)
Exposure	Particulate matter (PM) 2.5		
Inclusion criteria	Children with asthma and/or allergic rhinitis Between the ages of 6 and 18 years		
Exclusion criteria	Active respiratory infection Use of systemic corticosteroids Smoking Use of air purifiers at home Recent (within 3 weeks) asthma related hospitalization or visits to the emergency department Any other serious chronic illnesses		
Intervention	**TIDieR Checklist criteria**	**Paper/Location**	**Details**
	Brief Name	P341	Air purifier on health outcomes and indoor particles in homes of children with allergic diseases
	Rationale/theory/Goal	P341	To examine whether the use of air purifiers reduces the levels of PM2.5 in a highly polluted city P341
	Materials used	P341	Air purifiers with a high-efficiency particulate air (HEPA) filter
	Procedures used	P342	At week 0, 2 air purifiers (model AX9000 and AX7000, Samsung, Suwon, Korea) with high-efficacy HEPA filters (>99.95% for 0.3 μm) were placed in the living rooms and bedrooms of the active group, respectively
	Provider	P342/346	Samsung Electronics, Ltd., Suwon, Korea
	Method of delivery	-	Not applicable
	Location	P342	Intervention delivered at home
	Duration	P342	12 weeks
	Intensity	-	Not applicable
	Tailoring/adaptation	-	Not applicable
	Modifications	-	Not applicable
	Planned treatment fidelity	-	Not applicable
	Actual treatment fidelity	-	Not applicable
	Other details	-	None
Comparison	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	P341	No intervention
	Rationale/theory/Goal	P341	-

Bibliographic reference	Park H K, Cheng K C, Tetteh A O et.al. 2017. "Effectiveness of air purifier on health outcomes and indoor particles in homes of children with allergic diseases in Fresno, California: A pilot study". Journal of Asthma 54(4):341-346.		
	Materials used	P342	No air purifiers were installed
	Procedures used	-	Not applicable
	Provider	-	Not applicable
	Method of delivery	-	Not applicable
	Location	P342	Intervention delivered at home
	Duration	P342	12 weeks
	Intensity	-	Not applicable
	Tailoring/adaptation	-	Not applicable
	Modifications	-	Not applicable
	Planned treatment fidelity	-	Not applicable
	Actual treatment fidelity	-	Not applicable
	Other details	-	None
Follow up	12 weeks		
Study Methods	Method of randomisation	Not reported	
	Method of allocation concealment	Not reported	
	Statistical method(s) used to analyse data	Differences between the 2 groups at 6 and 12 weeks were analysed by the Student's t-test. When not distributed normally, differences were analysed by the Mann–Whitney U-test. Differences with P values of less than .05 (2-tailed) were considered statistically significant	
	Unit of allocation	Individual	
	Unit of analysis	Individual	
	Attrition	Number of participants completing the study: 17	Reasons for not completing the study: not reported
Outcomes measures and effect size.	Mean ± SEM for nasal symptom scores in allergic rhinitis patients during the study periods.		
	Health outcome	Active Group	Control Group
	Total Nasal Symptom Score	5.5 ± 0.5	8.6 ± 0.9
Risk of bias (ROB)	**Outcome**	**Judgement**	**Comments**
	Random sequence generation	High	Not reported
	Allocation concealment	High	Not reported
	Blinding of participants and personnel	High	Not reported
	Blinding of outcome assessment	High	Not reported

Bibliographic reference	Park H K, Cheng K C, Tetteh A O et.al. 2017. "Effectiveness of air purifier on health outcomes and indoor particles in homes of children with allergic diseases in Fresno, California: A pilot study". Journal of Asthma 54(4):341-346.		
	Incomplete outcome data	Low	1 person (5.5%) missing from final analysis
	Selective reporting	Low	Pre-specified outcomes reported
	Other sources of bias	None	None
Overall ROB	High		
Source of funding	Study was supported by Health Home funding from Samsung Electronics, Ltd., Suwon, Korea and the Sean N. Parker Centre of Allergy and Asthma Research at Stanford University, Stanford, CA, USA.		
Comments	Authors report that was not possible to perfectly match the control group homes to the active group homes in terms of PM levels at baseline due to differences in home design, size, and the differences in the frequency and types of indoor activities of the families living in each home		

D.3 NO2

Howden-Chapman 2008

Bibliographic reference	Howden-Chapman P, Pierse N, Nicholls S et.al. 2008. "Effects of improved home heating on asthma in community dwelling children: randomised controlled trial". BMJ (Clinical research ed.) 337:a1411.		
Registration	Not reported		
Study type	Cluster randomised controlled study		
Study dates	June 2005 to winter of 2007		
Objective	To assess whether non-polluting, more effective home heating (heat pump, wood pellet burner, flued gas) has a positive effect on the health of children with asthma.		
Country/ Setting	New Zealand		
Number of participants	409 children with asthma		
Participant characteristics	Demographic characteristics	Intervention group (n = 175)	Control group (n = 174)
		n (%)	n (%)
	Age (years) Mean (no)	10.06 (175)	10.02 (174)
	Sex (male)	54.29 (95)	60.34 (105)
	Ethnicity		
	Maori	34.86 (61)	37.36 (65)

Bibliographic reference	Howden-Chapman P, Pierse N, Nicholls S et.al. 2008. "Effects of improved home heating on asthma in community dwelling children: randomised controlled trial". BMJ (Clinical research ed.) 337:a1411.		
	Pacific peoples	13.14 (23)	7.47 (13)
	Other	52.00 (91)	43.68 (76)
	Socio-economic status (education)	Not reported	Not reported
	Building characteristics		
	Gas heating before study	55.43 (97)	59.20 (103)
	Existing condition		
	Family history of asthma	53.71 (94)	54.02 (94)
Exposure	NO2		
Inclusion criteria	Family lived in a study area and had a child aged between 6 and 12 years with doctor diagnosed asthma and symptoms in the past 12 months Child slept at least four nights a week in the house The house contained a less effective form of heating (Unflued gas or plug-in electric heaters) The family intended to live in the house over the two winter periods The homeowner agreed that the household could take part in the study		
Exclusion criteria	Not reported		
Intervention	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	P1	Home heating on asthma
	Rationale/theory/Goal	P2	Investigate the impact of a heating intervention on symptoms of asthma in children in homes that had been insulated before
	Materials used	P2	A non-polluting, more effective replacement heater (heat pump, wood pellet burner, flued gas)
	Procedures used		Homeowners chose a replacement heater (heat pump, wood pellet burner, flued gas) for their existing heaters
	Provider	-	Not applicable
	Method of delivery	-	Not applicable
	Location	P2	Intervention delivered at home
	Duration	P2	12 months
	Intensity	-	Not applicable
	Tailoring/adaptation	-	Not applicable
	Modifications	-	Not applicable

Bibliographic reference	Howden-Chapman P, Pierse N, Nicholls S et.al. 2008. "Effects of improved home heating on asthma in community dwelling children: randomised controlled trial". BMJ (Clinical research ed.) 337:a1411.		
	Planned treatment fidelity	-	Not applicable
	Actual treatment fidelity	-	Not applicable
	Other details	-	None
Comparison	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	P1	Home heating on asthma
	Rationale/theory/Goal	P2	Investigate the impact of a heating intervention on symptoms of asthma in children in homes that had been insulated before
	Materials used	P3	The control group received a replacement heater at the end of the trial
	Procedures used	-	Not applicable
	Provider	-	Not applicable
	Method of delivery	-	Not applicable
	Location	-	Intervention delivered at home
	Duration	P2	12 months
	Intensity	-	Not applicable
	Tailoring/adaptation	-	Not applicable
	Modifications	-	Not applicable
	Planned treatment fidelity	-	Not applicable
	Actual treatment fidelity	-	Not applicable
	Other details	-	None
Follow up	12 months		
Study Methods	Method of randomisation	Not reported	
	Method of allocation concealment	Not reported	
	Statistical method(s) used to analyse data	The binary information (for example, dry cough at night yes or no) was analysed using both standard generalised linear models and analysis of covariance (adjusting for outcome at baseline) generalised linear models with the logistic link function	
	Unit of allocation	House	
	Unit of analysis	Individual. Intra-cluster correlation coefficient was not reported	
	Attrition	Number of participants completing the study: 349	Reasons for not completing the study: Moved

Bibliographic reference	Howden-Chapman P, Pierse N, Nicholls S et.al. 2008. "Effects of improved home heating on asthma in community dwelling children: randomised controlled trial". BMJ (Clinical research ed.) 337:a1411.		
			Non-contactable Child moved No children with asthma Heating changed No longer interested Bereavement Unknown withdrawals
Outcomes measures and effect size.	Effect of heating intervention on parent reported health outcomes in children		
	Health outcome	% with outcome in control group	Adjusted Odds ratio (95% CI)
	Attacks of wheezing	43	0.71 (0.45 to 1.11)
	Dry cough at night	66	0.52 (0.32 to 0.83)
Risk of bias (ROB)	Outcome	Judgement	Comments
	Random sequence generation	High	Not reported
	Allocation concealment	High	Not reported
	Blinding of participants and personnel	Unclear	Not possible to blind the participants to their allocation
	Blinding of outcome assessment	Unclear	Not possible to blind field workers at home visits
	Incomplete outcome data	Low	12.5 % loss to follow up in the intervention group and 16.7 % loss to follow up in the control group. Loss unlikely to affect estimate
	Selective reporting	Low	Pre-specified outcomes reported in analysis
	Other sources of bias	None	None
Overall ROB	High risk		
Source of funding	Health Research Council of New Zealand, Contact Energy; Ministry for the Environment, Hutt Valley district health board, Capital and Coast district health board, Housing New Zealand, Energy Efficiency and Conservation Authority, and the LPG Association		
Comments			
Additional references	Free S, Howden-Chapman P, Pierse N, Viggers H, Housing Heating, Health Study Research, and Team. 2010. "More effective home heating reduces school absences for children with asthma". Journal of epidemiology and community health 64(5):379-86. Howden-Chapman P, Crane J, Matheson A, Viggers H, Cunningham M, Blakely T, O'Dea D, Cunningham C, Woodward A, Saville-Smith K, Baker M, and Waipara N (2005) Retrofitting houses with insulation to reduce health inequalities: Aims and methods of a clustered, randomised community-based trial. Social Science and Medicine 61(12), 2600-2610		

D.4 Mould

Burr 2007

Bibliographic reference	Burr M L, Matthews I P, Arthur R A, Watson H L, Gregory C J, Dunstan F D. J, and Palmer S R. 2007. "Effects on patients with asthma of eradicating visible indoor mould: a randomised controlled trial". Thorax 62(9):767-72.		
Registration	Not reported		
Study type	Cluster randomised controlled study		
Study dates	Not reported		
Objective	To investigate whether the eradication of visible mould from the houses of patients with asthma led to any improvement in their condition		
Country/ Setting	United Kingdom		
Number of participants	232 patients, 164 houses		
Participant characteristics	Demographic characteristics	Intervention group (81 houses; n = 115)	Control group (83 houses, n = 117)
		n (%)	n (%)
	Age (years) Mean (SD)	26.4 (16.2)	27.1 (16.0)
	Sex (male)	44 (38.2)	49 (41.8))
	Ethnicity	Not reported	Not reported
	Socio-economic status (education)	Not reported	Not reported
	Building characteristics	Not reported	Not reported
	Existing condition		
	Wheeze in last 4 weeks	85 (74)	95 (81)
	Rhinitis	74 (64)	71 (61)
Exposure	Mould		
Inclusion criteria	Symptoms of asthma in the last 12 months and indoor mould		
Exclusion criteria	Not reported		
Intervention	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	P767	Visible indoor mould and asthma
	Rationale/theory/Goal	P767	Eradicating visible indoor and its effect on people asthma
	Materials used	P768	Positive ventilation fan Mould removal Fungal application
	Procedures used	P768	Installation of positive ventilation fan (Drimaster) 2-step mould removal process: 1) application of aqueous preparation (RLT Bactdet) containing detergent and fungicide

Bibliographic reference	Burr M L, Matthews I P, Arthur R A, Watson H L, Gregory C J, Dunstan F D. J, and Palmer S R. 2007. "Effects on patients with asthma of eradicating visible indoor mould: a randomised controlled trial". Thorax 62(9):767-72.		
			(sodium dichlorophen) to remove mould from surfaces; 2) application of surface-penetrating aqueous preparation (RLT Halophen) containing fungicide (dialkyl dimethylammonium chloride)
	Provider	-	Householders
	Method of delivery	-	Not applicable
	Location	P768	Intervention delivered at home
	Duration	P768	12 months
	Intensity	-	Not applicable
	Tailoring/adaptation	-	Not applicable
	Modifications	-	Not applicable
	Planned treatment fidelity	-	Not applicable
	Actual treatment fidelity	-	Not applicable
	Other details	-	None
Comparison	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	P767	Visible indoor mould and asthma
	Rationale/theory/Goal	P767	Eradicating visible indoor and its effect on people asthma
	Materials used	P768	Control group was offered an anti mould kit 1 year later
	Procedures used	-	Not applicable
	Provider	-	Not applicable
	Method of delivery	-	Not applicable
	Location	-	Intervention delivered at home
	Duration	P768	12 months
	Intensity	-	Not applicable
	Tailoring/adaptation	-	Not applicable
	Modifications	-	Not applicable
	Planned treatment fidelity	-	Not applicable
	Actual treatment fidelity	-	Not applicable
	Other details	-	None
Follow up	12 months		
Study Methods	Method of randomisation	Randomisation stratified according to the built form of the houses	

Bibliographic reference	Burr M L, Matthews I P, Arthur R A, Watson H L, Gregory C J, Dunstan F D. J, and Palmer S R. 2007. "Effects on patients with asthma of eradicating visible indoor mould: a randomised controlled trial". Thorax 62(9):767-72.			
	Method of allocation concealment	Serially numbered sealed envelopes		
	Statistical method(s) used to analyse data	A multilevel multinomial model, with subjects nested in households to allow for the cluster sampling, was fitted using MLwiN Version 2.01		
	Unit of allocation	Households		
	Unit of analysis	Individual		
	Attrition	Number of participants completing the study: 211		Reasons for not completing the study: Not reported.
Outcomes measures and effect size.	Changes in variability of peak expiratory flow rate (PEFR) at 12 months			
		Intervention	Control	Difference (95% CI)
		Mean (SD)	Mean (SD)	
	CV of morning PEFR	-1.62 (6.47)	-2.08 (5.96)	0.46 (-1.58, 2.50)
	CV of evening PEFR	-1.30 (6.04)	-2.72 (6.30)	1.42 (-0.58 to 3.43)
Risk of bias (ROB)	**Outcome**	**Judgement**	**Comments**	
	Random sequence generation	High	Not reported	
	Allocation concealment	Low	Serially numbered sealed envelopes	
	Blinding of participants and personnel	Unclear	Not possible to blind the participants to their allocation in the trial	
	Blinding of outcome assessment	High	Not reported	
	Incomplete outcome data	High	19% loss to follow up in the intervention group and 30% loss to follow up in the control group. Loss to follow up likely to affect estimate.	
	Selective reporting	Low	Pre-specified outcomes reported in analysis	
	Other sources of bias	None	None	
Overall ROB	High risk			
Source of funding	Funding was received from Asthma UK (grant number 01/025), the Medical Research Council (grant number G9900679) and the Welsh Office of Research and Development (grant number S01/001)			
Comments	None			

Howden-Chapman 2007

Bibliographic reference	Howden-Chapman P, Matheson A, Crane J et.al. 2007. Effect of insulating existing houses on health inequality: cluster randomised study in the community. BMJ, doi:10.1136/bmj.39070.573032.80
Registration	Not reported

Bibliographic reference	Howden-Chapman P, Matheson A, Crane J et.al. 2007. Effect of insulating existing houses on health inequality: cluster randomised study in the community. BMJ, doi:10.1136/bmj.39070.573032.80		
Study type	Cluster randomised controlled study		
Study dates	2001 to 2002		
Objective	To assess whether retrofitting houses with insulation increased the indoor temperature and lowered the relative humidity, energy consumption and mould growth in the houses, as well as improved the health and well-being of the occupants		
Country/ Setting	New Zealand		
Number of participants	1350 households (4407 people)		
Participant characteristics	Demographic characteristics	Intervention group (n = 2262)	Control group (n = 2145)
		n (%)	n (%)
	Age (years)		
	0-4	294/2262 (13)	248/2145 (12)
	5-14	565/2262 (25)	522/2145 (24)
	15-24	230/2262 (10)	236/2145 (11)
	25-44	594/2262 (26)	590/2145 (28)
	45-64	391/2262 (17)	362/2145 (17)
	≥65	188/2262 (8)	187/2145 (9)
	Sex (female)	1185/2262 (52)	1112/2145 (52)
	Ethnicity		
	Maori	1106/2196 (50)	1001/2109 (48)
	Pacific peoples	501/2196 (23)	578/2109 (27)
	Other	877/2196 (40)	826/2109 (39)
	Socio-economic status (education)	Not reported	Not reported
	Building characteristics	Not reported	Not reported
	Existing condition		
	Health rated fair or poor	445/2243 (20)	437/2131 (21)
Exposure	Mould growth		
Inclusion criteria	House had to be uninsulated At least one person in each household with some respiratory disease, most commonly asthma, or chronic bronchitis and emphysema with preference being given to households with severe symptoms Households had to be planning to stay in their house for the next two winters		
Exclusion criteria	Not reported		
Intervention	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	P1	Effect of insulating existing houses on health inequality

Bibliographic reference	Howden-Chapman P, Matheson A, Crane J et.al. 2007. Effect of insulating existing houses on health inequality: cluster randomised study in the community. BMJ, doi:10.1136/bmj.39070.573032.80		
	Rationale/theory/Goal	P1	To determine whether insulating existing houses increases indoor temperatures and improves occupants' health and wellbeing.
	Materials used	P3	Retrofitting insulation package consisting of insulation in the ceiling, draught-stopping, sisalated paper (insulated foil) and a polyethylene covering
	Procedures used	P3	Installing ceiling insulation, draught stopping around windows and doors, and fitting sisalated paper beneath floor joists and a polythene moisture barrier on the ground beneath the house
	Provider	-	Not reported
	Method of delivery	-	Not applicable
	Location	P3	Intervention delivered at home
	Duration	P3	12 months
	Intensity	-	Not applicable
	Tailoring/adaptation	-	Not applicable
	Modifications	-	Not applicable
	Planned treatment fidelity	-	Not applicable
	Actual treatment fidelity	-	Not applicable
	Other details	-	None
Comparison	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	P1	Effect of insulating existing houses on health inequality
	Rationale/theory/Goal	P1	To determine whether insulating existing houses increases indoor temperatures and improves occupants' health and wellbeing.
	Materials used	P3	Households in the control group were insulated for equity at the end of the study after all data had been collected
	Procedures used	-	Not applicable
	Provider	-	Not applicable
	Method of delivery	-	Not applicable
	Location	P3	Intervention delivered at home
	Duration	P3	12 months
	Intensity	-	Not applicable
	Tailoring/adaptation	-	Not applicable

Bibliographic reference	Howden-Chapman P, Matheson A, Crane J et.al. 2007. Effect of insulating existing houses on health inequality: cluster randomised study in the community. BMJ, doi:10.1136/bmj.39070.573032.80		
	Modifications	-	Not applicable
	Planned treatment fidelity	-	Not applicable
	Actual treatment fidelity	-	Not applicable
	Other details	-	None
Follow up	24 months		
Study Methods	Method of randomisation	Not reported	
	Method of allocation concealment	Not reported	
	Statistical method(s) used to analyse data	Data analysed on an intention-to-treat basis. The analysis of covariance (ANCOVA) conducted controlling for the clustering of individuals within households and households within regions. Authors adjusted variables for age, sex, region, and baseline values.	
	Unit of allocation	Houses	
	Unit of analysis	Individual. Intra-cluster correlation coefficient was not reported	
	Attrition	Number of participants completing the study: 1128 households (3312 people)	Reasons for not completing the study: Moved Health reasons Unknown
Outcomes measures and effect size.	Health outcomes in trial of insulating houses after intervention		
	Health outcome	Intervention group	Control group
	Wheezing in past 3 months (participants with data for both years)	412 (1409)	544 (1366)
Risk of bias (ROB)	**Outcome**	**Judgement**	**Comments**
	Random sequence generation	High	Not reported
	Allocation concealment	High	Not reported
	Blinding of participants and personnel	Unclear	Households knew their houses had been insulated
	Blinding of outcome assessment	Low	Interviewers and the researchers did not know which households had been assigned to each group
	Incomplete outcome data	Low	25% total loss to follow up
	Selective reporting	Low	Pre-specified outcomes reported in analysis
	Other sources of bias	None	None
Overall ROB	High risk		

Bibliographic reference	Howden-Chapman P, Matheson A, Crane J et.al. 2007. Effect of insulating existing houses on health inequality: cluster randomised study in the community. BMJ, doi:10.1136/bmj.39070.573032.80
Source of funding	The Health Research Council of New Zealand, the Energy Efficiency and Conservation Authority, the Ministry of Health, Solid Energy, Orion, Christchurch City Council, Environment Canterbury, Hutt Mana Community Trust, MARIA, Eastern Bay of Plenty Energy Trust, Wellington City Council, and Housing New Zealand Corporation.
Comments	None

D.5 CO2

Kovesi 2009

Bibliographic reference	Kovesi T, Zaloum C, Stocco C, Fugler D, Dales R E, Ni A, Barrowman N, Gilbert N L, and Miller J D. 2009. "Heat recovery ventilators prevent respiratory disorders in Inuit children". Indoor air 19(6):489-99.		
Registration	Not reported		
Study type	Randomised controlled study		
Study dates	October 2006 and March 2007		
Objective	To evaluate the effect of Heat recovery ventilators (HRVs) on the respiratory health of young Inuit children in Qikiqtaaluk Region		
Country/ Setting	Canada		
Number of participants	68 homes		
Participant characteristics	Demographic characteristics	Active heat recovery ventilator	Placebo heat recovery ventilator
		n (%)	n (%)
	Age (months) Mean (SD)	30.5 (14.8)	22.4 (15.1)
	Sex (male)	16/26 (61.5)	16/25 (64.0)
	Ethnicity	Not reported	Not reported
	Socio-economic status (education)	Not reported	Not reported
	Building characteristics		
	Detached	19/25 (76.0)	18/23 (78.3)
	Duplex	6/25 (24)	5/23 (21.7)
	Type of heating		
	Forced air	18/25 (72.0)	20/23 (87.0)

Bibliographic reference	Kovesi T, Zaloum C, Stocco C, Fugler D, Dales R E, Ni A, Barrowman N, Gilbert N L, and Miller J D. 2009. "Heat recovery ventilators prevent respiratory disorders in Inuit children". Indoor air 19(6):489-99.		
	Radiator heat	7/25 (28.0)	3/23 (13.0)
	Existing condition		
	Reported wheeze with colds prior to study	12/26 (46.2)	7/25 (28.0)
Exposure	CO2		
Inclusion criteria	Infants and children below 6 years of age Communities with a high proportion of houses heated using ducted heating systems, rather that electric baseboard or hot water radiator systems		
Exclusion criteria	Not reported		
Intervention	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	P489	Heat recovery ventilators in preventing respiratory disorders in children
	Rationale/theory/Goal	P490	To evaluate the effect of Heat recovery ventilators (HRVs) on the respiratory health of young children
	Materials used	P490	Active heat recovery ventilators
	Procedures used	P490	Active HRVs were programmed by Venmar Ventilation Inc. to provide ventilation rate of 25–30 l/s
	Provider	P490	Venmar Constructo 1.0 heat recovery ventilators (Venmar Ventilation Inc., Drummondville, QC, Canada)
	Method of delivery	-	Not applicable
	Location	P490	Intervention delivered at home
	Duration	P489	6 months
	Intensity	-	Not applicable
	Tailoring/adaptation	-	Not applicable
	Modifications	-	Not applicable
	Planned treatment fidelity	-	Not applicable
	Actual treatment fidelity	-	Not applicable
	Other details	-	None
Comparison	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	P489	Heat recovery ventilators prevent respiratory disorders in children
	Rationale/theory/Goal	P490	To evaluate the effect of Heat recovery ventilators (HRVs) on the respiratory health of young children
	Materials used	P490	Non-active (placebo) heat recovery ventilators

Bibliographic reference	Kovesi T, Zaloum C, Stocco C, Fugler D, Dales R E, Ni A, Barrowman N, Gilbert N L, and Miller J D. 2009. "Heat recovery ventilators prevent respiratory disorders in Inuit children". Indoor air 19(6):489-99.			
	Procedures used	P490	Placebo units were configured to circulate air within the house, but not to increase the supply of fresh, outside air to the house.	
	Provider	P490	Venmar Constructo 1.0 heat recovery ventilators (Venmar Ventilation Inc., Drummondville, QC, Canada)	
	Method of delivery	-	Not applicable	
	Location	P490	Intervention delivered at home	
	Duration	P489	6 months	
	Intensity	-	Not applicable	
	Tailoring/adaptation	-	Not applicable	
	Modifications	-	Not applicable	
	Planned treatment fidelity	-	Not applicable	
	Actual treatment fidelity	-	Not applicable	
	Other details	-	None	
Follow up	6 months			
Study Methods	Method of randomisation	Random numbers table		
	Method of allocation concealment	Allocation concealment was achieved by carrying out randomisation off-site		
	Statistical method(s) used to analyse data	The odds of reporting symptoms of wheezing, cough, and upper respiratory tract infection in each group were analysed over time using a logistic marginal model with generalized estimating equations using an exchangeable working correlation matrix		
	Unit of allocation	Houses		
	Unit of analysis	Children		
	Attrition	Number of participants completing the study: not reported	Reasons for not completing the study: 6 houses not powered (Clyde River) 3 families withdrew consent 3 families withdrew consent & dismantled or removed HRV 4 children moved/adopted 1 HRV motor failed	
Outcomes measures and effect size.	Odds ratios (OR) for rhinitis and wheezing for children in houses with active or placebo heat recovery ventilators			
	Health outcome	HRV (OR)	Placebo (OR)	OR HRV/placebo (95%CI)
	Wheezing	0.00	1.00	0.00 (0.0074, 0.36)

Bibliographic reference	Kovesi T, Zaloum C, Stocco C, Fugler D, Dales R E, Ni A, Barrowman N, Gilbert N L, and Miller J D. 2009. "Heat recovery ventilators prevent respiratory disorders in Inuit children". Indoor air 19(6):489-99.			
	Rhinitis	1.00	1.67	0.60 (0.083, 3.86)
Risk of bias (ROB)	**Outcome**	**Judgement**	**Comments**	
	Random sequence generation	Low	Random numbers table	
	Allocation concealment	Low	Achieved by carrying out randomisation off-site	
	Blinding of participants and personnel	Low	Unit installation nor which units were active or placebos, were relayed by the study engineers to the occupants during the study	
	Blinding of outcome assessment	Low	Unit installation nor which units were active or placebos, were relayed by the study engineers to the study personnel or research assistants during the study	
	Incomplete outcome data	Low	51 houses included in the intention-to-treat analysis	
	Selective reporting	High	Symptoms were monitored for 6 months but authors only reported significant results in month 1 and 4	
	Other sources of bias	None	None	
Overall ROB	Low			
Source of funding	Venmar Ventilation Inc. provided the HRVs at the cost of manufacture and provided technical expertise to our engineers on a pro bono basis. The project purchased the parts and units and paid all shipping costs using funding from the Program of Energy Research and Development (Natural Resources Canada) and Canada Mortgage and Housing Corporation			
Comments	None			

Pet dander

Francis 2003

Bibliographic reference	Francis H, Fletcher G, Anthony C, et al. Clinical effects of air filters in homes of asthmatic adults sensitized and exposed to pet allergens. Clin Exp Allergy 2003 ;33(1):101-5.
Registration	Not reported
Study type	RCT
Study dates	Not reported

Bibliographic reference	Francis H, Fletcher G, Anthony C, et al. Clinical effects of air filters in homes of asthmatic adults sensitized and exposed to pet allergens. Clin Exp Allergy 2003 ;33(1):101-5.		
Objective	To assess the effect of using air cleaners in addition to HEPA vacuum cleaners over HEPA vacuum cleaners alone of asthma outcomes.		
Country/ Setting	UK/home		
Number of participants	30		
Participant characteristics	Demographic characteristics	HEPA air cleaner and HEPA vacuum	HEPA vacuum alone
	Age, mean (95% CI):	36.8 (29.3 to 44.3)	41.6 (34.4 to 48.9)
	% Male:	23.2% (not reported by groups)	
	Race:	Not reported in the study	
	Homeownership:	Not reported in the study	
	Geographic environment:	Not reported in the study	
	Clinical factors		
	Sensitization: (skin prick test positive):		
	Can f 1:	N=29/30	
	Fel d 1:	N=29/30	
	FEV1 % predicted, mean (95% CI):	87.3 (80.3 to 94.2)	88.8 (76.8 to 100.8)
	PC20, geometric mean (95% CI):	0.19 (0.07 to 0.56)	0.23 (0.08 to 0.68)
	Current smoker, n:	1	3
	Atopy		
	Alternaria:	N=25/30	
	HDM	N=30/30	
	Grass pollen:	N=30/30	
Exposure	Pet dander		
Inclusion criteria	• Adults with asthma between 18 and 65 years of age, • Own a dog or cat against medical advice • Have a positive skin prick test (weal of 3mm or more after correction or negative control value) to the relevant animal.		
Exclusion criteria	Not reported		
Intervention	TIDieR Checklist criteria	Paper/Location	Details
	Study details extracted from the Agency for Healthcare Research and Quality (AHRQ) comparative effectiveness review on 'Indoor Allergen Reduction in Management of Asthma 2018		
	Brief Name	-	HEPA air cleaner and HEPA vacuum
	Rationale/theory/Goal	-	
	Materials used	-	Air cleaners were placed in living

Bibliographic reference	Francis H, Fletcher G, Anthony C, et al. Clinical effects of air filters in homes of asthmatic adults sensitized and exposed to pet allergens. Clin Exp Allergy 2003 ;33(1):101-5.		
			rooms and bedrooms, and participants were instructed to vacuum carpets at least twice per week
	Procedures used	-	NA
	Provider	-	NA
	Method of delivery	-	NA
	Location	-	NA
	Duration	-	NA
	Intensity	-	NA
	Tailoring/adaptation	-	NA
	Modifications	-	NA
	Planned treatment fidelity	-	NA
	Actual treatment fidelity	-	NA
	Other details	-	NA
Comparison	TIDieR Checklist criteria	Paper/Location	Details
	Brief Name	-	HEPA vacuum alone
	Rationale/theory/Goal	-	NA
	Materials used	-	NA
	Procedures used	-	NA
	Provider	-	NA
	Method of delivery	-	NA
	Location	-	NA
	Duration	-	NA
	Intensity	-	NA
	Tailoring/adaptation	-	NA
	Modifications	-	NA
	Planned treatment fidelity	-	NA
	Actual treatment fidelity	-	NA
	Other details	-	NA
Follow up	12 months		
Study Methods	Method of randomisation	Not reported	
	Method of allocation concealment	Not reported	
	Statistical method(s) used to analyse data	Improvement in asthma outcome was compared using X^2 test	
	Unit of allocation	Individual	
	Unit of analysis	Individual	
	Attrition	0%	

Bibliographic reference	Francis H, Fletcher G, Anthony C, et al. Clinical effects of air filters in homes of asthmatic adults sensitized and exposed to pet allergens. Clin Exp Allergy 2003 ;33(1):101-5.		
Outcomes measures and effect size.	Primary outcomes		
		HEPA air cleaner and HEPA vacuum	HEPA vacuum alone
	FEV1, L, mean (SD) at 12 months:	2.84 (0.87) N = 15	2.59 (0.89) N = 15
Risk of bias (ROB)	**Outcome**	**Judgement**	**Comments**
	Random sequence generation	Unclear	Insufficient description of randomization;
	Allocation concealment	Unclear	Insufficient description of allocation concealment
	Blinding of participants and personnel	High	Patients not blinded;
	Blinding of outcome assessment	Low	-
	Incomplete outcome data	Low	All patients completed follow-up
	Selective reporting	Low	-
	Other sources of bias	Low	
Overall ROB	Low		
Source of funding	Not reported		
Comments	No		

Appendix E: Forest plots

No forest plots were created for this evidence review

Appendix F: GRADE profiles

F.1 House dust mite

Quality assessment							No of participants		Relative effect (95% CI)	Absolute effect	Quality
No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	intervention	Control			
Atopic dermatitis (continuous) (Better indicated by lower values) – mattress and pillow cover											
Tan 1996	randomised trials	serious risk of bias[1]	no serious inconsistency[2]	no serious indirectness[3]	no serious imprecision[4]	none	28	20		MD 4.2 lower (6.7 to 1.7 lower)	MODERATE
Quality of life (follow-up 12 months; Better indicated by lower values) – HMRV											
Wright 2009	randomised trials	no serious risk of bias[5]	no serious inconsistency[6]	no serious indirectness[3]	very serious imprecision[8]	none	60	59		Adj MD 2.83 lower (7.82 lower to 2.16 higher)	LOW
Asthma control questionnaire (ACQ) (follow-up 12 months; Better indicated by lower values) – HMRV											
Wright 2009	randomised trials	no serious risk of bias[5]	no serious inconsistency[2]	no serious indirectness[6]	serious imprecision[7]	none	60	59		Adj MD 0.25 lower (0.57 lower to 0.08 higher)	MODERATE
Respiratory health effect for example symptoms, pulmonary physiology (follow-up 12 months; Better indicated by higher values) – HMRV											
Wright 2009	randomised trials	no serious risk of bias[5]	no serious inconsistency[2]	no serious indirectness[6]	very serious imprecision[8]	none	60	59		MD 1.32 higher (2.56 lower to 5.19 higher)	LOW

[1] Downgraded once due to concerns over unequal attrition rate between groups (6.7% vs 33.3%)
[2] Not applicable as a single study
[3] Not downgraded as study met eligibility criteria as per protocol
[4] Not downgraded as the lower and upper confidence intervals excludes the default MID effect size of 0.5.
[5] Not downgraded as study was judged to be of low risk of bias
[6] Not applicable as a single study
[7] Downgraded once as the lower confidence interval crosses the effect size of 0.5
[8] Downgraded twice as the lower and upper confidence intervals crosses the effect size of 0.5

F.2 Particulate matter

Quality assessment							No of participants		Relative Effect (95% CI)	Absolute effect	Quality
No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Intervention	Control			
Quality of life (follow-up 12 months; Better indicated by lower values) – improved technology wood burning stove											
Noonan 2017	randomised trials	serious[1]	no serious inconsistency[2]	no serious indirectness[3]	very serious[4]	none	22	23	-	MD 0.18 lower (0.33 lower to 0.69 higher)	VERY LOW
Quality of life (follow-up 12 months; Better indicated by lower values) – air filtration device											
Noonan 2017	randomised trials	serious[1]	no serious inconsistency[2]	no serious indirectness[3]	Serious[5]	none	46	23	-	MD 0.07 lower (0.47 lower to 0.34 higher)	LOW
Respiratory health effect for example symptoms, pulmonary physiology; (follow-up 12 months; Better indicated by higher values) – improved technology wood burning stove											

Quality assessment							No of participants		Relative Effect (95% CI)	Absolute effect	Quality
No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Intervention	Control			
Noonan 2017	randomised trials	serious[6]	no serious inconsistency[2]	no serious indirectness[3]	serious imprecision[7]	none	22	23	-	MD 3.6 higher (6.8 lower to 14 higher)	LOW
Respiratory health effect for example symptoms, pulmonary physiology; (follow-up 12 months; Better indicated by higher values) – functioning air filtration device											
Noonan 2017	randomised trials	very serious[6]	no serious inconsistency[2]	no serious indirectness[3]	serious imprecision[7]	none	46	23	-	MD 0.71 lower (8.9 lower to 7.5 higher)	VERY LOW
Respiratory health effect for example symptoms, pulmonary physiology; (follow-up 12 weeks; Better indicated by higher values) – HEPA filter											
Park 2017	randomised trials	serious[6]	no serious inconsistency[2]	no serious indirectness[3]	no serious imprecision[8]	none	9	8	-	MD 3.10 lower (5.12 to1.08 lower)	MODERATE

[1] Downgraded once for lack of randomisation and allocation concealment
[2] Not applicable as a single study
[3] Not downgraded as study met eligibility criteria as per protocol
[4] Downgraded twice as the upper and lower confidence interval includes 0.32 (calculated from 0.5 SD of the control group)
[5] Downgraded once as the lower confidence interval includes calculated MID for this outcome measure 0.32 (calculated from 0.5 SD of the control group)
[6] Downgraded once for lack of randomisation, allocation concealment. Due to the type of intervention, the committee did not consider blinding to be of importance)
[7] Downgraded once as the upper confidence interval includes 9.49 (calculated from 0.5 SD of the control group) [8] Not downgraded as the upper and lower confidence interval does not include1.27 (calculated from 0.5 SD of the control group)

F.3 Gases (NO2, CO2)

Quality assessment							No of participants		Relative Effect (95% CI)	Absolute effect	Quality
No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Intervention	Control			
Respiratory health effect for example symptoms, pulmonary physiology; (follow-up mean 12 months) – replacement heater											
Howden-chapman 2008	randomised trials	serious[1]	no serious inconsistency[2]	no serious indirectness[3]	serious imprecision[7]	none	175	174	OR 0.71 (0.45 to 1.11)	Number of events not reported	LOW
Respiratory health effect for example symptoms, pulmonary physiology; (follow-up mean 6 months) – mechanical heat recovery ventilator											
Kovesi 2009	randomised trials	no serious risk of bias[5]	no serious inconsistency[2]	no serious indirectness[3]	no serious imprecision[4]	none	31	37	OR 0.00 (0.0074 to 0.36)	Number of events not reported	HIGH
Rhinitis (follow-up 6 months) – heat recovery ventilator											
Kovesi 2009	randomised trials	no serious risk of bias[5]	no serious inconsistency[2]	no serious indirectness[3]	very serious imprecision[6]	none	31	37	OR 0.06 (0.083 to 3.86)	Number of events not reported	LOW

[1] Downgraded once for lack of detail on randomisation and allocation concealment
[2] Not applicable as a single study
[3] Not downgraded as study met eligibility criteria as per protocol
[4] Not downgraded as confidence interval excludes appreciable harm and benefit
[5] Not downgraded as study was judged to be of low risk of bias
[6] Downgraded twice as confidence interval includes appreciable benefit (0.80) and harm (1.25)

[7] Downgraded once as confidence interval crosses line of no effect and includes appreciable benefit (0.80)

F.4 Mould

Quality assessment							No of participants		Relative (95% CI)	Absolute effect	Quality
No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Intervention	Control			
Respiratory health effect (follow-up 12 months; Better indicated by lower values) – positive ventilation fan, mould and fungal removal											
Burr 2007	randomised trials	serious[1]	no serious inconsistency[2]	no serious indirectness[3]	no serious imprecision[4]	none	81	83	-	MD 0.46 higher (1.58 lower to 2.50 higher)	MODERATE
Respiratory health effect (follow-up 24 months) – retrofitting insulation pack											
Howden-Chapman 2007	randomised trials	serious[5]	no serious inconsistency[2]	no serious indirectness[3]	no serious imprecision[6]	none	2775	544	OR 0.62 (0.53 to 0.73)	107 fewer per 1000 (from 72 fewer to 139 fewer)	MODERATE

[1] Downgraded once for lack of randomisation. Due to the type of intervention, the committee did not consider blinding to be of importance
[2] Not applicable as a single study
[3] Not downgraded as study met eligibility criteria as per protocol
[4] Not downgraded as the lower and upper confidence interval crosses does not include 3.05 in either direction (calculated from 0.5 SD of the control group)
[5] Downgraded once for lack of randomisation. Due to the type of intervention, the committee did not consider blinding to be of importance
[6] Not downgraded as confidence interval excludes appreciable benefit (0.80) and harm (1.25)

F.5 Pet dander

Quality assessment	No of participants	Relative Effect	Absolute effect	Quality

No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Intervention	Control	(95% CI)		
Respiratory health effect (follow-up 12 months) (Better indicated by higher values) – HEPA cleaner and vacuum											
Francis 2003	randomised trials	no serious risk of bias[1]	no serious inconsistency[2]	no serious indirectness[3]	serious[4]	none	15	15	-	MD 0.25 higher (0.38 lower to 0.88 higher)	MODERATE

[1] Not downgraded as study was judged to be of low risk of bias
[2] Not applicable as a single study
[3] Not downgraded as study met eligibility criteria as per protocol
[4] Downgraded as the upper confidence interval crosses includes 0.45 (calculated from 0.5 SD of the control group)

Appendix G: Economic evidence study selection

Please see health economic report

Appendix H: Health economic evidence tables

Please see health economic report

Appendix I: Health economic evidence profiles

Please see health economic report

Appendix J: Health economic analysis

Please see health economic report

Appendix K: Excluded studies

K.1 Public health studies

Bibliography	Reason for exclusion
Aas K. 1971. "Hyposensitization in house dust allergy asthma. A double-blind controlled study with evaluation of the effect on bronchial sensitivity to house dust". Acta paediatrica scandinavica 60(3):264-268.	Study not concerned with material and structural interventions but with hyposensitisation injection treatment
Abbott J, Cameron J, and Taylor B. 1981. "House dust mite counts in different types of mattresses, sheepskins and carpets, and a comparison of brushing and vacuuming collection methods". Clinical Allergy 11(6):589-595.	Not RCT. Study concerned with reducing house dust mite allergen concentration and does not address pre-specified health outcomes
Antonicelli L, Bilo M B, Pucci S, Schou C, and Bonifazi F. 1991. "Efficacy of an air-cleaning device equipped with a high efficiency particulate air filter in house dust mite respiratory allergy". Allergy 46(8):594-600.	Cross-over study. Already included parallel RCTs addressing same intervention
Arshad S H, Bateman B, and Matthews S M. 2003. "Primary prevention of asthma and atopy during childhood by allergen avoidance in infancy: a randomised controlled study". Thorax 58(6):489-93.	Study concerned with behavioural interventions and not on structural or material interventions
Barn P, Gombojav E, Ochir C et.al. 2018. "The effect of portable HEPA filter air cleaners on indoor PM2.5 concentrations and second hand tobacco smoke exposure among pregnant women in Ulaanbaatar, Mongolia: The UGAAR randomized controlled trial". Science of the Total Environment 615:1379-1389.	Study concerned with reducing particulate matter (PM) concentration but country not similar to the UK. We have included studies on PM with health outcomes
Batterman S, Du L, Mentz G, Mukherjee B, Parker E, Godwin C, Chin J Y, O'Toole A, Robins T, Rowe Z, and Lewis T. 2012. "Particulate matter concentrations in residences: an intervention study evaluating stand-alone filters and air conditioners". Indoor air 22(3):235-52.	Study concerned with reducing particulate matter (PM) concentration and does not address pre-specified health outcomes. We have included studies on PM with health outcomes
Berings M, Jult A, Vermeulen H, Ruyck N, Derycke L, Ucar H, Ghekiere P, Temmerman R, Ellis J, Bachert C, Lambrecht Bn, Dullaers M, and Gevaert P. 2017. "Probiotics-impregnated bedding covers in house dust mite allergic rhinitis patients: a double-blind, randomised, placebo-controlled, crossover clinical trial". Allergy 72:23-23.	Conference abstract only
Bernstein J A, Brandt D, Rezvani M, Abbott C, and Levin L. 2009. "Evaluation of cleaning activities on respiratory symptoms in asthmatic female homemakers". Annals of Allergy, and Asthma and Immunology 102(1):41-46.	Not RCT. Study concerned with cleaning activities and not on structural or material interventions

Bibliography	Reason for exclusion
Bessot Jc, Moreau G, Lenz D et.al. 1974. "A double blind comparative desensitization trial with house dust and mite extracts". Revue francaise d'allergologie ET d'immunologie clinique 15:73-80.	Study not in English language
Bowler S D, Mitchell C A, and Miles J. 1985. "House dust control and asthma: a placebo-control trial of cleaning air filtration". Annals of allergy 55(3):498-500.	Not RCT
Bryant-Stephens T, Kurian C, Guo R et.al 2009. "Impact of a household environmental intervention delivered by lay health workers on asthma symptom control in urban, disadvantaged children with asthma". American journal of public health 99 Suppl 3:S657-65.	Study concerned with evaluating the changes in participant behaviour
Burr M L, Dean B V, Merrett T G et.al 1980. "Effects of anti-mite measures on children with mite-sensitive asthma: a controlled trial". Thorax 35(7):506-12.	Study interested in behavioural changes to remove mites from beddings
Celano MP, Holsey CN, and Kobrynski LJ. 2012. "Home-based family intervention for low-income children with asthma: a randomized controlled pilot study". Journal of family psychology: JFP: journal of the Division of Family Psychology of the American Psychological Association (Division 43) 26(2):171-8.	Study not concerned with material and structural intervention but with repeated home visits by trained specialists
Chan-Yeung M, Ferguson A, Watson W, Dimich-Ward H, Rousseau R, Lilley M, Dybuncio A, and Becker A. 2005. "The Canadian Childhood Asthma Primary Prevention Study: outcomes at 7 years of age". Journal of allergy and clinical immunology 116(1):49-55.	Study not concerned with material and structural intervention but with behavioural strategies to reduce house dust mite
Chan-Yeung Moira, Ferguson Alexander, Dimich-Ward Helen, Watson Wade, Manfreda Jure, and Becker Allan. 2002. "Effectiveness of and compliance to intervention measures in reducing house dust and cat allergen levels". Annals of allergy, asthma & immunology: official publication of the American College of Allergy, Asthma, and & Immunology 88(1):52-8.	Study concerned with reducing house allergen concentration and does not address pre-specified health outcomes
Chuang Hsiao-Chi, Ho Kin-Fai, Lin Lian-Yu, Chang Ta-Yuan, Hong Gui-Bing, Ma Chi-Ming, Liu I Jung, and Chuang Kai-Jen. 2017. "Long-term indoor air conditioner filtration and cardiovascular health: A randomized crossover intervention study". Environment international 106:91-96.	Country not similar to the UK Cross-over study. Already included parallel RCTs addressing same intervention
Cloosterman S G, Hofland I D, Lukassen H G et.al. 1997. "House dust mite avoidance measures improve peak flow and symptoms in patients with allergy but without asthma: a possible delay in the manifestation of clinical asthma?" The Journal of allergy and clinical immunology 100(3):313-9.	Study not concerned with material and structural intervention but with house dust mite avoidance measures.

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Colloff M J, Lever R S, and McSharry C. 1989. "A controlled trial of house dust mite eradication using natamycin in homes of patients with atopic dermatitis: effect on clinical status and mite populations". The British journal of dermatology 121(2):199-208.	Study not concerned with material and structural intervention but with chemical intervention (natamycin spray)
Cote J, Cartier A, Robichaud P et.al. 2000. "Influence of asthma education on asthma severity, quality of life and environmental control". Canadian respiratory journal 7(5):395-400.	Study not concerned with material and structural intervention but with education programs based on self-management
Corver K, Kerkhof M, Brussee J E, Brunekreef B, Van Strien , R T, Vos A P, Smit H A, Gerritsen J, Neijens H J, De Jongste , and J C. 2006. "House dust mite allergen reduction and allergy at 4 yr: Follow up of the PIAMA-study". Pediatric Allergy and Immunology 17(5):329-336.	Study not concerned with material and structural intervention but on behavioural intervention
Cox Jennie, Isiugo Kelechi, Ryan Patrick, Grinshpun Sergey A, Yermakov Michael, Desmond Colleen, Jandarov Roman, Vesper Stephen, Ross James, Chillrud Steven, Dannemiller Karen, and Reponen Tiina. (2018). Effectiveness of a portable air cleaner in removing aerosol particles in homes close to highways. Indoor Air, 28(6), pp.818-827.	Cross-over study. Already included parallel RCTs addressing same intervention
Crisafulli D, Almqvist C, Marks G, and Tovey E. 2007. "Seasonal trends in house dust mite allergen in children's beds over a 7-year period". Allergy: European Journal of Allergy and Clinical Immunology 62(12):1394-1400.	Study concerned with reducing house dust mite allergen concentration and does not address pre-specified health outcomes. We have included studies on HDM with health outcomes
Cui X, Li F, Xiang J, Fang L, Chung M K, Day D B, Mo J, Weschler C J, Gong J, He L, Zhu D, Lu C, Han H, Zhang Y, and Zhang J J. 2018. "Cardiopulmonary effects of overnight indoor air filtration in healthy non-smoking adults: A double-blind randomized crossover study". Environment International 114:27-36.	Country not similar to the UK. Cross-over study. Already included parallel RCTs addressing same intervention
Custovic A, Simpson B M, Murray C S et.al. Asthma N A. C. Manchester, Allergy Study, and Group. 2002. "The National Asthma Campaign Manchester Asthma and Allergy Study". Pediatric allergy and immunology: official publication of the European Society of Pediatric Allergy and Immunology 13 Suppl 15:32-7.	Study not concerned with material and structural intervention but with multicomponent interventions. Health outcomes for the randomised subgroup not reported
Custovic A, Simpson B M, Simpson A et.al. 2000. "Manchester Asthma and Allergy Study: low-allergen environment can be achieved and maintained during pregnancy and in early life". The Journal of allergy and clinical immunology 105(2 Pt 1):252-8.	Study not concerned with material and structural intervention but with multicomponent interventions. Health outcomes for the randomised subgroup not reported

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de Vries MP, van den Bemt L, Aretz K, et al. House dust mite allergen avoidance and self-management in allergic patients with asthma: randomised controlled trial. Br J Gen Pract. 2007 Mar;57(536):184-90. PMID: 17359604	Study not concerned with material and structural intervention but on behavioural intervention
Dharmage S, Walters EH, Thien F, et al. Encasement of bedding does not improve asthma in atopic adult asthmatics. Int Arch Allergy Immunol. 2006 Jan;139(2):132-8.	Study not concerned with material and structural intervention but on behavioural intervention
Edwards R T, Neal R D, Linck P et.al 2011. "Enhancing ventilation in homes of children with asthma: cost-effectiveness study alongside randomised controlled trial". The British journal of general practice: the journal of the Royal College of General Practitioners 61(592):e733-41.	Study concerned with improving air exchange rates and not on material and structural interventions
Eggleston P A, Butz A, Rand C et.al. 2005. "Home environmental intervention in inner-city asthma: A randomized controlled clinical trial". Annals of Allergy, and Asthma and Immunology 95(6):518-524.	Study concerned with behavioural interventions
Fukuie T, Nomura I, Narita M, Suzuki T, Tajima I, and Natsume O. 2013. "A randomized, open-label, parallel group study to evaluate the efficacy and safety of proactive management in pediatric subjects with moderate to severe atopic dermatitis". Journal of allergy and clinical immunology. 131(2 suppl. 1):Ab101.	Conference abstract only
Gehring U, de Jongste J C, Kerkhof M et.al. 2012. "The 8-year follow-up of the PIAMA intervention study assessing the effect of mite-impermeable mattress covers". Allergy 67(2):248-56.	Study not concerned with material and structural intervention but on behavioural intervention
Gillespie-Bennett J, Pierse N, Wickens K et.al. 2008. "Sources of nitrogen dioxide (NO2) in New Zealand homes: findings from a community randomized controlled trial of heater substitutions". Indoor air 18(6):521-8.	Study not concerned with material and structural intervention but with sources and concentration of NO2
Glasgow NJ, Ponsonby AL, Kemp A, et al. Feather bedding and childhood asthma associated with house dust mite sensitisation: a randomised controlled trial. Arch Dis Child. 2011 Jun;96(6):541-7.	Intervention not of interest
Glover Mt, and Atherton Dj. 1991. "A double-blind controlled trial of hyposensitisation to the house dust mite in childhood atopic eczema". British journal of dermatology 125(Suppl 38):87.	Conference abstract only
Gutgesell C, Heise S, Seubert S, Seubert A, Domhof S, Brunner E, and Neumann C. 2001. "Double-blind placebo-controlled house dust mite control measures in adult patients with atopic dermatitis". The British journal of dermatology 145(1):70-4.	Study concerned with reducing house dust mite allergen concentration and does not address pre-specified health outcomes. We have included studies on HDM with health outcomes

Bibliography	Reason for exclusion
Halken Susanne, Host Arne, Niklassen Ulla et.al. 2003. "Effect of mattress and pillow encasings on children with asthma and house dust mite allergy". The Journal of allergy and clinical immunology 111(1):169-76.	Data not usable. Only p values reported
Halmerbauer G, Gartner C, Schierl M et.al. 2003. "Study on the Prevention of Allergy in Children in Europe (SPACE): Allergic sensitization at 1 year of age in a controlled trial of allergen avoidance from birth". Pediatric Allergy and Immunology 14(1):10-17.	Study not concerned with material and structural intervention but with educational advice on food allergy and mite prevention
Harving H, Korsgaard J, and Dahl R (1994) Clinical efficacy of reduction in house-dust mite exposure in specially designed, mechanically ventilated "healthy" homes. Allergy 49(10), 866-70	Not RCT
Hide D W, Matthews S, Tariq S, and Arshad S H. 1996. "Allergen avoidance in infancy and allergy at 4 years of age". Allergy 51(2):89-93.	Study not concerned with material and structural intervention but with breast feeding and low allergen diet
Holm L, Bengtsson A, van Hage-Hamsten , M , Ohman S, and Scheynius A. 2001. "Effectiveness of occlusive bedding in the treatment of atopic dermatitis--a placebo-controlled trial of 12 months' duration". Allergy 56(2):152-8.	Not RCT
Htut T, Higenbottam T W, Gill G W, Darwin R, Anderson P B, and Syed N (2001) Eradication of house dust mite from homes of atopic asthmatic subjects: a double-blind trial. The Journal of allergy and clinical immunology 107(1), 55-60	Data not usable
Hughes S C, Bellettiere J, Nguyen B, Liles S, Klepeis N E, Quintana P J. E, Berardi V, Obayashi S, Bradley S, Hofstetter C R, and Hovell M F. 2018. "Randomized Trial to Reduce Air Particle Levels in Homes of Smokers and Children". American Journal of Preventive Medicine 54(3):359-367.	Study concerned with reducing air particle concentration and does not address pre-specified health outcomes. We have included studies on particulate matter with health outcomes
Hyndman S J, Vickers L M, Htut T, Maunder J W, Peock A, and Higenbottam T W. 2000. "A randomized trial of dehumidification in the control of house dust mite". Clinical and experimental allergy: journal of the British Society for Allergy and Clinical Immunology 30(8):1172-80.	Study concerned with reducing house dust mite concentration and does not address pre-specified health outcomes
Iversen M, Bach E, and Lundqvist G R. 1986. "Health and comfort changes among tenants after retrofitting of their housing". Environment International 12(1-4):161-166.	Not RCT (Controlled observational design)
Jirapongsananuruk O, Malainual N, Sangsupawanich P, Aungathiputt V, and Vichyanond P. 2000. "Partial mattress encasing significantly reduces house dust mite antigen on bed sheet surface: A controlled trial". Annals of Allergy, and Asthma and Immunology 84(3):305-310.	Country not similar to the UK

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Joseph KE, Adams CD, Cottrell L et.al. 2003. "Providing dust mite-proof covers improves adherence to dust mite control measures in children with mite allergy and asthma". Annals of allergy, asthma & immunology: official publication of the American College of Allergy, Asthma, and & Immunology 90(5):550-3.	RCT was abandoned before publication of results
Kajbafzadeh M, Brauer M, Karlen B et.al. 2015. "The impacts of traffic-related and wood smoke particulate matter on measures of cardiovascular health: a HEPA filter intervention study". Occupational and environmental medicine 72(6):394-400.	Study concerned with PM2.5 concentration and not on pre-specified health outcomes
Karottki D G, Spilak M, Frederiksen M et.al. 2013. "An indoor air filtration study in homes of elderly: cardiovascular and respiratory effects of exposure to particulate matter". Environmental health: a global access science source 12:116.	Cross-over study. Already included parallel RCTs addressing same intervention
Kercsmar Carolyn M, Dearborn Dorr G, Schluchter Mark, Xue Lintong, Kirchner H Lester, Sobolewski John, Greenberg Stuart J, Vesper Stephen J, and Allan Terry (2006) Reduction in asthma morbidity in children as a result of home remediation aimed at moisture sources. Environmental health perspectives 114(10), 1574-80	Data not usable Data on symptom days report in graph format only
Kim J, Kim H, Lim D et.al. 2016. "Effects of Indoor Air Pollutants on Atopic Dermatitis". International journal of environmental research and public health 13(12).	Country not similar to the UK
Kniest Fm, Young E, Praag Mc et.al. 1991. "Clinical evaluation of a double-blind dust-mite avoidance trial with mite-allergic rhinitic patients". Clinical and experimental allergy 21(1):39-47.	Study not concerned with material and structural intervention but with chemical agent and not on structural or material interventions
Koopman L P, van Strien R T, Kerkhof M et.al. Prevention, Incidence of, Asthma, Mite Allergy, and Study. 2002. "Placebo-controlled trial of house dust mite-impermeable mattress covers: effect on symptoms in early childhood". American journal of respiratory and critical care medicine 166(3):307-13.	Study not concerned with material and structural intervention
Kolokotroni Maria, and Littler John. (1995). Effectiveness of Extractor Fans in Reducing Airborne Moisture in Homes. Indoor Air, 5(1), pp.69-75.	Not RCT
Lajoie P, Aubin D, Gingras V et.al 2015. "The IVAIRE project--a randomized controlled study of the impact of ventilation on indoor air quality and the respiratory symptoms of asthmatic children in single family homes". Indoor air 25(6):582-97.	Study concerned with improving air exchange rates and not on material and structural interventions
Lee IS. Effect of bedding control on amount of house dust mite allergens, asthma symptoms, and	Study not concerned with material and structural

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peak expiratory flow rate. Yonsei Med J. 2003 Apr 30;44(2):313-22. PMID: 12728474.	intervention but with boiling bed covers and exposing them to sunlight
Lee Yj, Bang Js, Oh Yj, Lee Jw, Sung Tj, Lee Kh, and Lee Hr (2015) Effect of vacuuming mattresses on allergic rhinitis symptoms in children. Allergy: European journal of allergy and clinical immunology. 70, 301	Conference abstract
Li H, Cai J, Chen R et.al. 2017. "Particulate Matter Exposure and Stress Hormone Levels: A Randomized, Double-Blind, Crossover Trial of Air Purification". Circulation 136(7):618-627.	Country not similar to the UK
Lioy P J, Yiin L M, Adgate J, Weisel C, and Rhoads G G. 1998. "The effectiveness of a home cleaning intervention strategy in reducing potential dust and lead exposures". Journal of exposure analysis and environmental epidemiology 8(1):17-35.	Not RCT. Study concerned with lead loading
Luczynska C, Tredwell E, Smeeton N, et al. A randomized controlled trial of mite allergen-impermeable bed covers in adult mite-sensitized asthmatics. Clin Exp Allergy. 2003 Dec; 33(12):1648-53.	Study not concerned with material and structural intervention but on behavioural intervention
McNamara M L, Thornburg J, Semmens E O, Ward T J, and Noonan C W. 2017. "Reducing indoor air pollutants with air filtration units in wood stove homes". Science of the Total Environment 592:488-494.	Study concerned with reducing endotoxin and PM2.5 concentration and does not address pre-specified health outcomes
Mihrshahi S, Marks G B, Criss S, Tovey E R, Vanlaar C H, Peat J K, and Team Caps. 2003. "Effectiveness of an intervention to reduce house dust mite allergen levels in children's beds". Allergy 58(8):784-9.	Study concerned with reducing house dust mite concentration and does not address pre-specified health outcomes. Studies on mattress covers with health outcomes already included
Min K T, Lundrigan P, Sward K, Collingwood S C, and Patwari N. (2018). Smart home air filtering system: A randomized controlled trial for performance evaluation. Smart Health, pp.	Study concerned with particulate matter concentration and does not address pre-specified health outcomes
Munir A K, Einarsson R, and Dreborg S K. 1993. "Vacuum cleaning decreases the levels of mite allergens in house dust". Paediatric allergy and immunology: official publication of the European Society of Paediatric Allergy and Immunology 4(3):136-43.	Study concerned with reducing mite allergen concentration and does not address pre-specified health outcomes
Murray A B, and Ferguson A C. 1983. "Dust-free bedrooms in the treatment of asthmatic children with house dust or house dust mite allergy: a controlled trial". Pediatrics 71(3):418-22.	Not RCT
Murray CS, Foden P, Sumner H, et al. Preventing severe asthma exacerbations in children: a	Study not concerned with material and structural

Bibliography	Reason for exclusion
randomised trial of mite impermeable bedcovers. Am J Respir Crit Care Med. 2017	intervention but on behavioural intervention
Nambu M, Shirai H, Sakaguchi M, Aihara M, and Takatori K. 2008. "Effect of house dust mite-free pillow on clinical course of asthma and IgE level - A randomized, double-blind, controlled study". Pediatric Asthma, and Allergy and Immunology 21(3):137-143.	Data on pre-specified health outcomes not reported
Nelson H S, and Skufca R M. 1991. "Double-blind study of suppression of indoor fungi and bacteria by the PuriDyne biogenic air purifier". Annals of allergy 66(3):263-6.	Not RCT
Neumayr A, Niebauer E, Weber N, and Haussinger K. 2011. "Reduction of house dust mite allergens by using a silver-doped sleeping system". Pravention und Rehabilitation 23(2):75-84.	Study not in English language
Newton Da, Maberley Dj, and Wilson R. 1978. "House dust mite hyposensitization". British journal of diseases of the chest 72(1):21-28.	Study concerned with behavioural interventions
Nogrady S G, and Furnass S B. 1983. "Ionisers in the management of bronchial asthma". Thorax 38(12):919-22.	Cross-over study. Already included parallel RCTs addressing same intervention
Oosting A, de Bruin-Weller MS, Terreehorst I et.al. 2002. "Effect of mattress encasings on atopic dermatitis outcome measures in a double-blind, placebo-controlled study: the Dutch mite avoidance study". The Journal of allergy and clinical immunology 110(3):500-6.	Data not usable. Median and ranges reported
Osman L M, Ayres J G, Garden C, Reglitz K, Lyon J, and Douglas J G. 2010. "A randomised trial of home energy efficiency improvement in the homes of elderly COPD patients". The European respiratory journal 35(2):303-9.	Study concerned with energy efficiency improvement not on indoor air pollutants
Paulin L M, Diette G B, Scott M et.al 2014. "Home interventions are effective at decreasing indoor nitrogen dioxide concentrations". Indoor air 24(4):416-24.	Study concerned with reducing NO_2 concentration. We have included studies on NO_2 with health outcomes.
Popplewell EJ, Innes VA, Lloyd-Hughes S, et al. The effect of high-efficiency and standard vacuum-cleaners on mite, cat and dog allergen levels and clinical progress. Pediatr Allergy Immunol 2000; 11(3):142-8.	Data not usable. Only p values reported
Postma Julie, Karr Catherine, and Kieckhefer Gail. 2009. "Community health workers and environmental interventions for children with asthma: a systematic review". The Journal of asthma: official journal of the Association for the Care of Asthma 46(6):564-76.	Systematic review concerned with community health workers and environmental interventions
Rabito FA, Carlson JC, He H, et al. A single intervention for cockroach control reduces cockroach exposure and asthma morbidity in	Study not concerned with material and structural intervention but with insecticide

Bibliography	Reason for exclusion
children. J Allergy Clin Immunol. 2017 Jan 10; S0091-6749(16):31349-5.	bait by pest control professionals
Ramsey Cd, Chan E, Chooniedass R, DyBuncio A, Rousseau R, Becker A, and Chan-Yeung M. 2013. "The canadian asthma primary prevention study (CAPPS): outcomes at 15 years of age". American journal of respiratory and critical care medicine 187.	Abstract on behavioural interventions
Reisman R E, Mauriello P M, Davis G B et.al. 1990. "A double-blind study of the effectiveness of a high-efficiency particulate air (HEPA) filter in the treatment of patients with perennial allergic rhinitis and asthma". The Journal of allergy and clinical immunology 85(6):1050-7.	Data not usable. Only p values reported
Rijssenbeek-Nouwens LH, Oosting AJ, de Bruin-Weller MS, et al. Clinical evaluation of the effect of anti-allergic mattress covers in patients with moderate to severe asthma and house dust mite allergy: a randomised double blind placebo controlled study. Thorax. 2002 Sep;57(9):784-90.	Data not usable. Median and ranges reported
Schonberger HJAM, Maas T, Dompeling E et.al 2004. "Compliance of asthmatic families with a primary prevention programme of asthma and effectiveness of measures to reduce inhalant allergens--a randomized trial". Clinical and experimental allergy: journal of the British Society for Allergy and Clinical Immunology 34(7):1024-31.	Study not concerned with material and structural intervention but with educational and behavioural interventions with the assistance of a special care group
Scott M, Roberts G, Kurukulaaratchy RJ et.al. 2012. "Multifaceted allergen avoidance during infancy reduces asthma during childhood with the effect persisting until age 18 years". Thorax 67(12):1046-51.	Study not concerned with material and structural intervention but with breast feeding and low allergen diet
Sheikh A, Hurwitz B, Sibbald B, et al. House dust mite barrier bedding for childhood asthma: randomised placebocontrolled trial in primary care [ISRCTN63308372]. BMC Fam Pract. 2002 Jun 18;1-6. PMID: 12079502	Study not concerned with material and structural intervention but on behavioural intervention
Singh M, and Jaiswal N. (2013). Dehumidifiers for chronic asthma. Cochrane Database of Systematic Reviews, 2013(6), pp.CD003563.	Systematic review. Studies checked for possible inclusion
Sporik R, Hill D J, Thompson P J, Stewart G A, Carlin J B, Nolan T M, Kemp A S, and Hosking C S. 1998. "The Melbourne House Dust Mite Study: long-term efficacy of house dust mite reduction strategies". The Journal of allergy and clinical immunology 101(4 Pt 1):451-6.	Study not concerned with material and structural intervention but with reducing house dust mite concentration and does not address pre-specified health outcomes
Stillerman A, Nachtsheim C, Li W et.al. 2010. "Efficacy of a novel air filtration pillow for avoidance of perennial allergens in symptomatic adults". Annals of allergy, asthma & immunology: official publication of the American College of Allergy, Asthma, and & Immunology 104(5):440-9.	Cross-over study. Already included parallel RCTs addressing same intervention

Bibliography	Reason for exclusion
Sulser C, Schulz G, Wagner P, et al. Can the use of HEPA cleaners in homes of asthmatic children and adolescents sensitized to cat and dog allergens decrease bronchial hyperresponsiveness and allergen contents in solid dust? Int Arch Allergy Immunol. 2008 Dec;148(1):23-30	Data not usable. Only p values and delta changes reported
Takaro Tim K, Krieger James W, and Song Lin. 2004. "Effect of environmental interventions to reduce exposure to asthma triggers in homes of low-income children in Seattle". Journal of exposure analysis and environmental epidemiology 14 Suppl 1:S133-43.	Study not concerned with material and structural intervention but with behavioural interventions with the assistance of community health workers
Tempels-Pavlica Z, Oosting A J, Terreehorst I, van Wijk , R Gerth, Bruijnzeel-Koomen C A. F. M, de Monchy , J G R, and Aalberse R C. 2004. "Differential effect of mattress covers on the level of Der p 1 and Der f 1 in dust". Clinical and experimental allergy: journal of the British Society for Allergy and Clinical Immunology 34(9):1444-7.	Study concerned with reducing house dust mite concentration and does not address pre-specified health outcomes. We have included studies on HDM with health outcomes
Terreehorst I, Hak E, Oosting AJ et.al. 2003. "Evaluation of impermeable covers for bedding in patients with allergic rhinitis". The New England journal of medicine 349(3):237-46.	Study not concerned with material and structural intervention but on behavioural intervention
Thiam D G, Tim C F, Hoon L S, Lei Z, and Bee-Wah L. 1999. "An evaluation of mattress encasings and high efficiency particulate filters on asthma control in the tropics". Asian Pacific journal of allergy and immunology 17(3):169-74.	Country not similar to the UK
Tsurikisawa N, Saito A, Oshikata C, Nakazawa T, Yasueda H, and Akiyama K. 2013. "Encasing bedding in covers made of microfine fibers reduces exposure to house mite allergens and improves disease management in adult atopic asthmatics". Allergy, and Asthma and Clinical Immunology 9(1):44.	Country not similar to the UK
Tsurikisawa N, Saito A, Oshikata C, et al. Effective allergen avoidance for reducing exposure to house dust mite allergens and improving disease management in adult atopic asthmatics. J Asthma. 2016, 53(8):843-53	Country not similar to the UK
van den Bemt L, de Vries MP, Cloosterman S, et al.(2007) Influence of house dust mite impermeable covers on health-related quality of life of adult patients with asthma: Results of a randomized clinical trial. J Asthma. 44(10):843-8.	Study not concerned with material and structural intervention but on behavioural intervention
van den Bemt , Lisette , van Knapen , Lieke , de Vries , Marjolein P, Jansen Margreet, Cloosterman Sonja, van Schayck , and Constant P. 2004. "Clinical effectiveness of a mite allergen-impermeable bed-covering system in asthmatic mite-sensitive patients". The Journal of allergy and clinical immunology 114(4):858-62.	Data on pre-specified health outcomes not reported

Bibliography	Reason for exclusion
van der Heide S, Kauffman HF, Dubois AE, et al. Allergen reduction measures in houses of allergic asthmatic patients: effects of air-cleaners and allergen-impermeable mattress covers. Eur Respir J. 1997 Jun; 10(6):1217-23.	Study concerned with reducing allergen concentration and does not address pre-specified health outcomes. We have included studies on pet allergen reduction with health outcomes
Verrall B, Muir D C, Wilson W M, Milner R, Johnston M, and Dolovich J. 1988. "Laminar flow air cleaner bed attachment: a controlled trial". Annals of allergy 61(2):117-22.	Crossover study and intervention not of interest
Weeks J, Oliver J, Birmingham K, Crewes A, and Carswell F. 1995. "A combined approach to reduce mite allergen in the bedroom". Clinical and experimental allergy: journal of the British Society for Allergy and Clinical Immunology 25(12):1179-83.	Study concerned with reducing house dust mite allergen concentration and does not address pre-specified health outcomes. We have included studies on HDM reduction with health outcomes
Weichenthal S, Mallach G, Kulka R et.al. 2013. "A randomized double-blind crossover study of indoor air filtration and acute changes in cardiorespiratory health in a First Nations community". Indoor air 23(3):175-84.	Cross-over study. Already included parallel RCTs addressing same intervention
Wickman M, Nordvall S L, Pershagen G, Korsgaard J, Johansen N, and Sundell J. 1994. "Mite allergens during 18 months of intervention". Allergy 49(2):114-9.	Not RCT
Wickman M, Paues S, and Emenius G. 1997. "Reduction of the mite-allergen reservoir within mattresses by vacuum- cleaning. A comparison of three vacuum-cleaning systems". Allergy: European Journal of Allergy and Clinical Immunology 52(11):1123-1127.	Not RCT
Winn Amber K, Salo Paivi M, Klein Cynthia, Sever Michelle L, Harris Shawn F, Johndrow David, Crockett Patrick W, Cohn Richard D, and Zeldin Darryl C. 2016. "Efficacy of an in-home test kit in reducing dust mite allergen levels: results of a randomized controlled pilot study". The Journal of asthma: official journal of the Association for the Care of Asthma 53(2):133-8.	Study not concerned with material and structural intervention but with strategies to reduce dust mite and does not address pre-specified health outcomes
Woodcock A, Forster L, Matthews E, et al. Control of exposure to mite allergen and allergen-impermeable bed covers for adults with asthma. N Engl J Med. 2003 Jul 17; 349(3):225-36.	Study not concerned with material and structural intervention but on behavioural intervention
Woodfine L, Neal RD, Bruce N et.al. 2011. "Enhancing ventilation in homes of children with asthma: pragmatic randomised controlled trial". The British journal of general practice: the journal of the Royal College of General Practitioners 61(592):e724-32.	Study concerned with improving air exchange rates and not on material and structural interventions

Bibliography	Reason for exclusion
Wood R A, Johnson E F, Van Natta , M L, Chen P H, and Eggleston P A. 1998. "A placebo-controlled trial of a HEPA air cleaner in the treatment of cat allergy". American journal of respiratory and critical care medicine 158(1):115-20.	Not RCT
Yodying J, and Phipatanakul W (2009) Effects of improved home heating on asthma in community dwelling children: Randomised controlled trial. Pediatrics 124(SUPPL. 2), S145	Commentary on a RCT

K.2 Economic studies

Please see health economic report

Appendix L: Research recommendations

L.1.1 Effective interventions to improve air quality in people without pre-existing health conditions

Population	Adults and children without pre-existing health conditions
Intervention	• Interventions to prevent exposure to volatile organic compounds (VOCs) • Interventions to prevent exposure to NO2 • Interventions to prevent exposure to damp and mould
Comparison	Other intervention or standard of care
Outcomes	• Respiratory health outcomes • Allergic health outcomes • Cardiac health outcomes • Pregnancy related health outcomes • Cancer health outcomes • Health related quality of life
Study design	• Randomised controlled trials • Cohort studies
Time frame	At least 1 year follow up

Rationale: Studies included in the evidence reviews only included people with asthma or other health conditions. These studies showed that different interventions are cost-effective in improving health outcomes for people with pre-existing health conditions as they can lead to savings for the NHS. However, as there was no evidence for people with no pre-existing health condition, we do not know if there are health benefits for these people. Also, it is not clear if these interventions are cost-effective in groups who do not have the same level of interaction with the NHS.

L.1.2 Effective intervention to identify, fix and prevent the recurrurence of damp and mould

Population	Adults and children without pre-existing health conditions
Intervention	• Interventions to identify damp and mould • Interventions to remedy damp and mould • Interventions to prevent recurrence of damp and mould
Comparison	Other intervention or standard of care
Outcomes	• Respiratory health outcomes • Allergic health outcomes • Cardiac health outcomes • Pregnancy related health outcomes • Cancer health outcomes • Health related quality of life

Population	Adults and children without pre-existing health conditions
Study design	• Randomised controlled trials • Cohort studies
Time frame	At least 1 year follow up

Rationale: Studies included in the evidence reviews only included people with asthma or other health conditions. These studies showed that different interventions are cost-effective in improving health outcomes for people with pre-existing health conditions as they can lead to savings for the NHS. However, as there was no evidence for people with no pre-existing health condition, we do not know if there are health benefits for these people. Also, it is not clear if these interventions are cost-effective in groups who do not have the same level of interaction with the NHS.