World Health Organization

WHO HOUSING AND HEALTH GUIDELINES

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Contents

Foreword

The quality of housing has major implications for people's health. Housing in cities is of particular concern, with the world's urban population predicted to double by 2050 and, with it, the demand for housing. In both developed and developing countries, improving housing conditions and reducing health risks in the home is thus critically important.

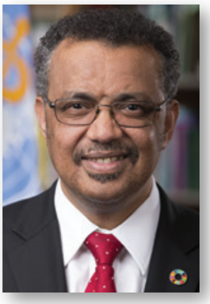
Improved housing conditions can save lives, reduce disease, increase quality of life, reduce poverty, help mitigate climate change and contribute to the achievement of a number of Sustainable Development Goals, including those addressing health (SDG 3) and sustainable cities (SDG 11). Housing is therefore a major entry point for intersectoral public health programmes and primary prevention.

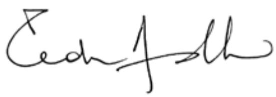
Ensuring everyone lives in healthy and safe dwellings has implications for national, regional and local governments, which set overall standards and determine the legal context for housing construction and renovation. With these guidelines, WHO provides evidence-based recommendations on conditions and interventions that promote healthy housing, and facilitates leadership in enabling health and safety considerations to underpin housing regulations.

By focusing on a sector, as opposed to a specific health risk, intervention, activity or policy, the guidelines combine existing WHO guidance on housing issues with new evidence-based recommendations. This provides accessible guidance, which will enable health considerations to inform housing, energy, community development, and urban development policies.

These guidelines will support country partners to develop tools and strategies for translating normative housing standards into national action. WHO will further strengthen its work with a broad network of international partners, including: WHO country and regional offices; ministries of health; ministries of building and construction; WHO collaborating centres; other United Nations agencies, particularly the United Nations Human Settlement Programme (UN-Habitat); and nongovernmental organizations.

Raising housing standards is a key pathway for providing healthy housing conditions and improving health and well-being for all.





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Abbreviations and acronyms

ADL	activities of daily living
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
B[a]P	benzo[a]pyrene
Bq/m^3	becquerel per cubic metre
CO	carbon monoxide
COPD	chronic obstructive pulmonary disease
DALYs	disability-adjusted life years
dB	decibel
EtD	evidence to decision
ERG	External Review Group
ERT	emission rate targets
GDG	Guideline Development Group
GRADE	Grading of Recommendations Assessment, Development and Evaluation
HHGL	WHO Housing and health guidelines
HWT	household water treatment
IADL	instrumental activities of daily living
IHD	ischaemic heart disease
IT	interim target
OR	odds ratio
PECO	participants, exposure, comparison, outcome
PICO	participants, intervention, comparison, outcomes
PM	particulate matter
SDGs	Sustainable Development Goals
SG	Steering Group
SHS	second-hand tobacco smoke
TB	tuberculosis
UNHCR	United Nations High Commissioner for Refugees
WASH	water, sanitation and hygiene
WHO	World Health Organization
WMO	World Meteorological Organization
WSP	water safety plan

Executive summary

Improved housing conditions can save lives, prevent disease, increase quality of life, reduce poverty, help mitigate climate change and contribute to the achievement of the Sustainable Development Goals (SDGs), including those addressing health (SDG 3) and sustainable cities (SDG 11). Housing is becoming increasingly important to health due to demographic and climate changes. The world's urban population is expected to double by 2050[1] and will require housing solutions. The world's population aged over 60 years of age, who tend to spend more time at home, will also double by 2050.[2] Changing weather patterns, associated with climate change, underline the importance of housing providing protection from cold, heat and other extreme weather events in order to promote resilient communities.

Housing can expose people to a number of health risks. As discussed in the *WHO Housing and health guidelines* (HHGL), structurally deficient housing increases the likelihood that people slip or fall, increasing the risk of injury. Poor accessibility to their house puts disabled and elderly people at risk of injury, stress and isolation. Housing that is insecure, sometimes due to affordability issues or weak security of tenure, is stressful. Housing that is difficult or expensive to heat contributes to poor respiratory and cardiovascular outcomes, while high indoor temperatures can cause heat-related illnesses and increase cardiovascular mortality. Indoor air pollution is connected to a wide range of noncommunicable disease outcomes, harms respiratory and cardiovascular health, and may trigger allergic and irritant reactions, such as asthma. Crowded housing increases the risk of exposure to infectious disease. Inadequate water supply and sanitation facilities affect food safety and personal hygiene, and therefore lead to the development of communicable diseases.

The quality and environmental context of housing are some of the main dimensions of environmental inequalities. Poor housing conditions are one of the mechanisms through which social and environmental inequality translates into health inequality, which further affects quality of life and well-being.

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1 Habitat III. Revised zero draft of the New Urban Agenda. Quito: United Nations; 2016.

2 World report on ageing and health. Geneva: World Health Organization; 2015.

In response to the above, the HHGL bring together the most recent evidence to provide practical recommendations to reduce the health burden due to unsafe and substandard housing conditions. They provide new guidance and recommendations relevant to inadequate living space (crowding), low and high indoor temperatures, injury hazards in the home, and accessibility of housing for people with functional impairments. In addition, the guidelines identify and summarize existing WHO guidelines and recommendations related to housing, with respect to water quality, air quality, neighbourhood noise, asbestos, lead, tobacco smoke and radon.

Drawing on a broad range of newly commissioned, or recently published, systematic reviews of the scientific literature, the guidelines apply strict criteria for assessing the quality of available evidence and its suitability for developing recommendations. The recommendations focus particular attention on reducing risk factors, while also recognizing the importance of key interventions. They encompass general considerations for policy and good practice recommendations for addressing health problems. The quality of the evidence is rated based on the risk of bias (and other quality features) in the included studies, inconsistency of results, indirectness, imprecision and other factors deemed relevant. Table 1 presents the new guidelines' recommendations.

The guidelines aim at informing housing policies and regulations at the national, regional and local level on the impact of housing on health. Therefore, the main target audience for the guidelines is policy-makers who are responsible for housing-related policies and regulations, enforcement measures, and initiating intersectoral collaboration that seeks to support healthy housing from a government perspective.

The guidelines are also intended to be relevant in the daily activities of implementing actors such as government agencies, architects, builders, housing providers, developers, engineers, urban planners, industry regulators, financial institutions, as well as social services, community groups, and public health professionals. These stakeholders are directly involved in the construction, maintenance and demolition of housing in ways that influence human health and safety.

Table 1 Recommendations of the WHO Housing and health guidelines

Topic	Recommendation	Strength of recommendation
Crowding	Strategies should be developed and implemented to prevent and reduce household crowding.	Strong
Indoor cold and insulation	Indoor housing temperatures should be high enough to protect residents from the harmful health effects of cold. For countries with temperate or colder climates, 18 °C has been proposed as a safe and well-balanced indoor temperature to protect the health of general populations during cold seasons.	Strong
	In climate zones with a cold season, efficient and safe thermal insulation should be installed in new housing and retrofitted in existing housing.	Conditional
Indoor heat	In populations exposed to high ambient temperatures, strategies to protect populations from excess indoor heat should be developed and implemented.	Conditional
Home safety and injuries	Housing should be equipped with safety devices (such as smoke and carbon monoxide alarms, stair gates and window guards) and measures should be taken to reduce hazards that lead to unintentional injuries.	Strong
Accessibility	Based on the current and projected national prevalence of populations with functional impairments and taking into account trends of ageing, an adequate proportion of the housing stock should be accessible to people with functional impairments.	Strong

While the guidelines provide global recommendations, their implementation and prioritization will vary depending on local contexts and will require national, regional and local adaptation. As a result, implementing the guidelines entails political will and coordination between different levels of governance: local, state and central governments; government departments; the health, private, nongovernmental and community sectors; and support and input from international development and finance organizations. It requires taking into account the need to address the social determinants of health, empower communities, tackle social and health inequalities, align local and global actors, and monitor.

WHO is preparing web-based guidance and tools that build on the evidence used to inform these guidelines and will work with Member States to support the implementation process through its regional and country offices.

1

Introduction

1 Introduction

The *WHO Housing and health guidelines* (HHGL) provide evidence-based recommendations for healthy housing conditions and interventions. This chapter introduces the WHO approach to healthy housing, outlines the key risks to health associated with the housing environment, and assesses the burden of disease associated with housing. Subsequently, the objectives, rational, target audience, scope, and co-benefits of the HHGL are introduced, as well as the relationship between the social determinants of health, housing and health.

1.1 Housing and health

1.1.1 WHO approach to healthy housing

Healthy housing is shelter that supports a state of complete physical, mental and social well-being. Healthy housing provides a feeling of *home*, including a sense of belonging, security and privacy. Healthy housing also refers to the physical structure of the dwelling, and the extent to which it enables physical health, including by being structurally sound, by providing shelter from the elements and from excess moisture, and by facilitating comfortable temperatures, adequate sanitation and illumination, sufficient space, safe fuel or connection to electricity, and protection from pollutants, injury hazards, mould and pests. Whether housing is healthy also depends on factors outside its walls. It depends on the local *community*, which enables social interactions that support health and well-being. Finally, healthy housing relies on the *immediate housing environment*, and the extent to which this provides access to services, green space, and active and public transport options, as well as protection from waste, pollution and the effects of disaster, whether natural or man-made *(1)*.

1.1.2 Key health risks related to housing

Exposures and health risks in the home environment are critically important because of the large amount of time people spend there. In high-income countries, around 70% of people's time is spent inside their home *(2)*. In some places, including where unemployment levels are higher, and where more people are employed in home-based industries, this percentage is even higher *(3)*. Children, the elderly, and those with a disability or chronic illness are likely to spend most of their time at home, and are therefore more exposed to health risks associated with housing *(2)*. Children are also at increased risk of the harms from some of the toxins that are present in some housing, such as those in lead paint *(4)*.

Housing will become increasingly important to health due to demographic and climate changes. The number of people aged over 60 years of age, who spend a larger proportion of their time at home, will double by 2050 *(5)*. The changing weather patterns associated with climate change also underline the importance of housing providing protection from cold, heat and extreme weather events *(6)*.

Poor housing can expose people to several health risks. For example, structurally deficient housing, due to poor construction or maintenance, can increase the likelihood that people slip or fall, increasing the risk of injury. Poor accessibility to homes may expose their disabled and elderly residents to the risk of injury, stress and isolation. Housing that is insecure, sometimes due to affordability issues or weak security of tenure, is stressful. Housing that is difficult or expensive to heat can contribute to poor respiratory and cardiovascular outcomes, while high indoor temperatures can increase cardiovascular mortality. Indoor air pollution harms respiratory health and may trigger allergic and irritant reactions, such as asthma. Crowded housing increases the risk of exposure to infectious disease and stress. Inadequate water supply and sanitation facilities affect food safety and personal hygiene. Urban design that discourages physical activity contributes to obesity and related conditions, such as diabetes, and poor mental and cardiovascular health. Unsafe building materials or building practices, or building homes in unsafe locations, can expose people to a range of risks, such as injury due to building collapse.

Housing in slums (the preferred term of UN-Habitat) and informal housing pose particular risks to health. Currently, around 1 billion people live in slum conditions today *(7)*, which often develop due to exclusion from planning processes. According to UN-Habitat, a "slum household" is a group of individuals under the same roof, in an urban area, lacking one or more of the following: durable housing (housing which fails to provide shelter from the elements); sufficient living space; security of tenure; sanitation and infrastructure; and access to improved (uncontaminated) water sources. Slum dwellers are therefore exposed to many of the risks associated with housing, such as structurally defective dwellings, inadequate housing facilities and overcrowding, but also face particular health risks from poor sanitation and unsafe electric connections, toxic building materials, unvented cooking facilities, and unsafe infrastructure, including roads. In addition, such settlements are sometimes in locations that are more likely to expose occupants to hazards such as landslides, floods and industrial pollution. In relation to well-being, the lack of legal title to homes is stressful and can expose slum dwellers to the risk of forced eviction *(8)*.

Slums and informal settlements often house migrants, refugees and internally displaced persons. More people are on the move now than ever before. There are an estimated 1 billion migrants in the world today: 250 million international migrants, and 763 million internal migrants. This number includes 65 million people, who have been forcibly displaced and require urgent housing solutions *(9)*.

1.1.3 Prevalence of poor housing conditions

Large numbers of people live in poor housing conditions. For example, 6% of households in Latin America and the Caribbean (compared with 0.4% in the European Union) have more than three people per room *(10)*. Some 9% of the global population has no access to an improved (uncontaminated) drinking-water source. Nearly half of all people using poor quality or contaminated drinking-water sources live in sub-Saharan Africa, while one fifth live in South Asia *(11)*. In addition, 41% of the world's population cook and heat their housing using open fires and simple stoves that burn solid fuels. These result in polluted indoor air *(12)* and inadequate ventilation.

Globally, many houses have structural defects. For example, 15% of the European population live in housing with a leaking roof, or damp walls, floors or foundations, or rot in window frames, floors and other structural elements *(13)*. Almost 20% report that their housing did not protect them against excessive heat during summer, while 13% report that their housing was not comfortably warm during winter *(13)*. In the United Kingdom, 72% of adults with mobility problems reported that the entry to their housing was not properly accessible *(14)*. In the United States of America, 5.2% of the housing stock is classified as inadequate, having either severe or moderate physical problems such as deficiencies in heating, plumbing or upkeep *(15)*.

1.1.4 Burden of disease associated with housing

Health conditions related to housing present an important health burden. Some of this is attributable to poor access to water and poor indoor environmental quality. Water, sanitation and hygiene (WASH) were responsible for 829 000 deaths from diarrhoeal disease worldwide in 2016. This constitutes 1.9% of the global burden of disease measured as disability-adjusted life years (DALYs) *(16)*. In 2016, 3.8 million deaths globally were attributable to household air pollution from the use of solid fuels for cooking, almost all of which occurred in low- and middle-income countries *(17)*. About 15% of new childhood asthma in Europe can be attributed to indoor dampness, representing over 69 000 potentially avoidable DALYs and 103 potentially avoidable deaths every year *(18)*.

Housing also contributes to the burden of disease through exposing people to dangerous substances or hazards, or to infectious diseases. For example, almost 110 000 people die every year in Europe as a result of injuries at home or during leisure activities, and a further 32 million require hospital admission because of such injuries *(19)*. In Europe, it has been estimated that 7500 deaths and 200 000 DALYs are attributable to lack of window guards and smoke detectors *(18)*. Approximately 10% of hospital admissions per year in New Zealand are attributable to household crowding *(20)*. In 2012, India recorded over 2600 deaths and 850 of various injuries resulting from the collapse of over 2700 buildings *(21)*. In Kyrgyzstan, household crowding causes 18.13 deaths per 100 000 from tuberculosis (TB) per year *(18)*. Exposure to lead is estimated to have caused 853 000 deaths in 2013 *(22)*.

While everyone can be exposed to the risks associated with unhealthy housing, people with low incomes and vulnerable groups are more likely to live in unsuitable or insecure housing, or to be denied housing altogether *(23)*. Inequalities associated with housing are discussed later in this chapter.

1.2 WHO Housing and health guidelines

1.2.1 Objectives and rationale for developing the WHO Housing and health guidelines

The impact of housing on health and the prevalence of poor housing conditions around the world, as presented in section 1.1, justify the need for globally acceptable and practical guidelines that will ensure healthy housing and human safety. The underlying principle of such guidelines is for housing to give adequate protection from all potential hazards prevailing in the local environment. This principle should apply to both the existing housing stock and newly constructed dwellings. Although a number of housing and health regulatory frameworks and guidelines exist, they are not comprehensively coordinated to address all aspects of housing, human health and safety. For instance, WHO has guidelines for indoor air quality or water and sanitation but there is a lack of comprehensive, international housing and health guidelines highlighting that these can be a fundamental way of improving population health *(1)*. While improving housing may not be the top policy priority in all countries, reliable global guidance for shaping current and future policy is the first step to protect people living in a range of climatic conditions from unhealthy housing. This is a critical public health priority. The improvements recommended by these guidelines relate to a large array of housing aspects, including vital infrastructure, the physical dwelling, the use of the dwelling, and the location of the dwelling. They must be viewed alongside each other so that policy-makers can make the most of co-benefits and synergies, while avoiding trade-offs *(24)*. Large benefits in cost–effectiveness would arise from addressing the health risks associated with housing simultaneously and this approach is in line with WHO's intersectoral work to create health-promoting environments *(25–28)*.

These HHGL add to existing WHO guidelines by providing evidence-based recommendations on healthy housing conditions and interventions that are not covered by the other guidelines, and by summarizing those relevant to housing and health. As sectoral guidelines, they represent a proactive step forward, highlighting the need to address the health risks associated with housing through a systems approach. By their nature, land use and building regulations act to address multiple risks, including structures and heating systems, as well as hazard avoidance. These HHGL, by providing access to the science on minimizing multiple health risks associated with housing, will be an important resource for Member States.

Implementing the HHGL will support the achievement of the Sustainable Development Goals (SDGs), including SDG 3 to ensure healthy lives and promote well-being for all age groups and SDG 11 to make cities and human settlements inclusive, safe, resilient and sustainable *(29)*. The HHGL will also be influential for ensuring availability of sanitation for all at household level (SDG 6), meeting targets for renewable energy and energy efficiency (SDG 7) and taking action to mitigate climate change (SDG 13) *(30)*. The importance of the sectoral approach has been recently emphasized in the New Urban Agenda for sustainable urban development established at Habitat III *(31)*.

The HHGL contribute towards ensuring Member States meet their obligations regarding the human right to adequate housing. This right to adequate housing is recognized in international human rights laws as a component of the right to an adequate standard of living, enshrined in the Universal Declaration of Human Rights (adopted in 1948) and the International Covenant on Economic, Social and Cultural Rights (adopted in 1966). For housing to be adequate, the following seven criteria must be met: security of tenure; availability of services, materials, facilities and infrastructure; affordability; habitability; accessibility; location; and cultural adequacy *(32, 33)*. Thus, the HHGL will inform regulations that aim to address and fulfil the above criteria of adequate housing. While the HHGL provide global recommendations, their implementation and prioritization will vary by local context and will require national and local adaptation.

1.2.2 Target audience

The main target audience for the guidelines is policy-makers who are responsible for housing-related policies and regulations, enforcement measures, and initiating intersectoral collaborations that seek to support healthy housing from a government perspective.

The guidelines are also of direct relevance to the daily work of implementing actors such as government agencies, architects, builders, housing providers, developers, engineers, urban planners, industry regulators, financial institutions, as well as social services, community groups, and public health professionals. These stakeholders are ultimately required to ensure that housing is built, maintained, renovated, used and demolished in ways that support health.

1.2.3 Scope

As already noted, "healthy housing" is associated with several factors, inside and outside the home. The HHGL do not address all possible risk factors related to housing but focus on priority areas that have not yet been addressed by existing WHO guidelines and where robust evidence is available. These were identified by the Guideline Development Group (GDG) established for this work (see Chapter 2).

The priority areas addressed by the HHGL are as follows:

- inadequate living space (crowding) (Chapter 3)
- low indoor temperatures (Chapter 4)
- high indoor temperatures (Chapter 5)
- injury hazards in the home (Chapter 6)
- accessibility of housing for people with functional impairments (Chapter 7).

In addition to the above, existing WHO guidelines and recommendations related to housing are identified and summarized in Chapter 8 to cover the following issues:

- water quality (section 8.1)
- air quality (section 8.2)
- tobacco smoke (section 8.3)
- noise (section 8.4)
- asbestos (section 8.5)
- lead (section 8.6)
- radon (section 8.7).

Guidance on other aspects of housing and buildings that relate to health – including pests, food safety and ventilation – are listed in section 8.8. Despite the range of issues covered, the list of relevant elements is not exhaustive. For instance, there are still a number of housing risk factors (such as lighting, height of ceilings and buildings, electric security, housing surroundings and fuel poverty) that have not been covered in the HHGL at this time. WHO is planning to continue investigating and working on other housing-related risk factors to health and to provide future guidance. At the same time, the HHGL do not distinguish between permanent housing and housing that is intended to be temporary, such as emergency shelter arrangements. However, the GDG recognizes that implementing the HHGL is likely to be more challenging in informal and emergency housing and will require different priorities, depending on the context. General implementation considerations and WHO's role in supporting these are discussed in Chapter 9. Important supplementary guidance relevant to emergency shelter arrangements are further provided by the Sphere Project *(34)*. Homelessness, which is the most extreme denial of the right to adequate housing, is not discussed as part of the HHGL *(35)*.

1.2.4 Co-benefits

Co-benefits arise from addressing the key health risks associated with housing. In many cases, a dwelling poses multiple risks to healthy housing. For example, a house may have poor indoor air quality, be cold, and have multiple injury hazards. Housing risks should therefore be viewed holistically and as components of an inter-related system in order to take advantages of the co-benefits presented by different interventions. For example, correcting structural defects reduces the risk of injury, improves thermal comfort, and reduces exposure to outdoor pollutants.

Housing interventions can also have indirect co-benefits for health. Improving thermal insulation, weatherization and ventilation, and installing energy-efficient heating (Chapters 4 and 5) can improve indoor temperatures that support health, while also lowering expenditure on energy *(24, 36)* and reducing carbon emissions *(37)*.

Improving housing conditions also supports other positive social outcomes. As discussed in Chapter 3, reducing crowding supports good health outcomes, but also contributes to improved educational outcomes, as children are able to study more effectively *(38)*. Improving thermal comfort through installing insulation and heating reduces days off school and work *(39)*. Improving housing can also create jobs and stimulate investment *(40)*. Therefore, addressing health risks associated with housing is likely to particularly benefit low-income and vulnerable groups, as these groups are more likely to live in inadequate housing.

In recent years, some countries have instituted new "green" standards for construction practices. These standards are aimed at addressing the design, location, and site of housing; promote water conservation and energy efficiency; encourage the use of building materials beneficial to the environment; and promote healthy living conditions *(41)*. Some green housing elements that are typically included in such standards are associated with health outcomes, including: energy efficient heating; improved ventilation; building materials free from formaldehyde, lead and asbestos; sound insulation; and no carpets in kitchens and bathrooms *(42)*.

The HHGL aim to ensure that occupants of green housing also enjoy health benefits *(18, 43)*. Studies of green and energy efficient housing improvements and their influence on health have recently been comprehensively reviewed *(44, 45)*.

1.2.5 Social determinants, housing and health

Choices of housing types, quality, size and location are shaped by a number of economic, social and demographic factors. These factors affect the features that the house will provide to its occupants (e.g. durability, building materials, accessibility etc.) and whether they can afford the cost of operating and maintaining it. The cost of maintaining and operating a house is of importance to human health and safety and includes: the purchase of safe drinking-water and of electricity or other fuel for heating the home *(27)*. Transport infrastructure can also be considered as an operational aspect of housing affordability, because it influences how much people need to pay to travel between their homes and work and other places.[3]

Globally, across low-, middle- and high-income countries, low-income earners are more likely to live in housing that exposes them to health risks. For example, in Cambodia, toilet facilities are only available to 29% of households in the lowest income quintile, compared with 79% of households in the highest income quintile *(47, 48)*. In Guatemala, 89% of the lowest income quintile have dirty floors, compared with 4% of the highest income quintile *(49–51)*. In the United States of America, repeated hospitalizations for childhood asthma are

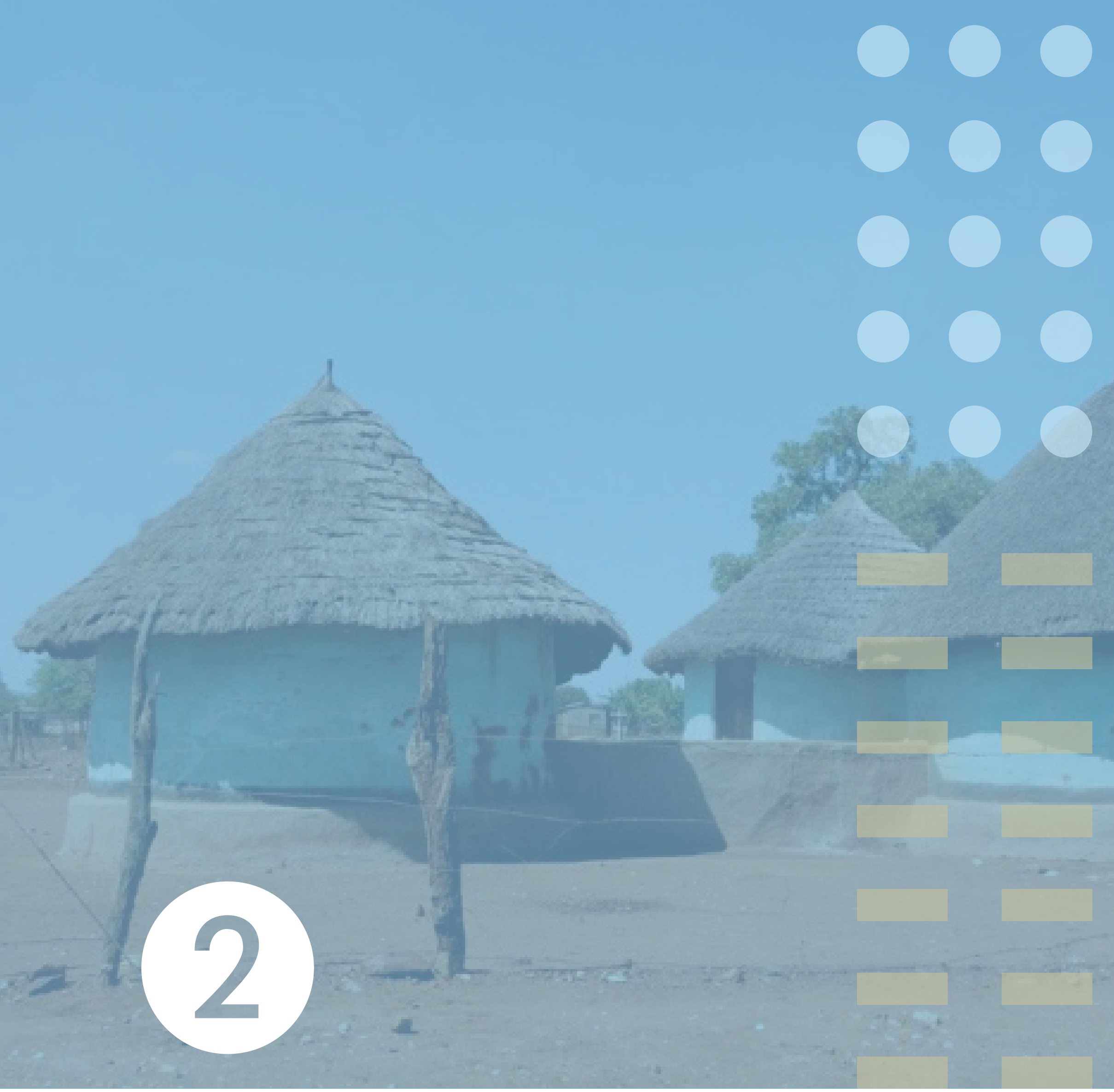
[3] Under the Right to Adequate Housing, it is understood that housing is not affordable if its cost threatens or compromises the occupants' enjoyment of other human rights; housing cannot be considered affordable if a household spends more than 30% of its disposable income on rent, operation, and maintenance costs *(33, 46)*.

correlated with residing in the census tract areas with the highest proportion of crowded housing conditions, the largest number of racial minorities and the highest neighbourhood-level poverty *(18, 52, 53)*.

This inequality in housing conditions goes beyond whether people are rich or poor. In some countries certain groups, including indigenous people, minority populations, single parent families, disabled people and women, are more likely to live in unsuitable housing *(54–57)*.

Poor health outcomes in turn can contribute to poor economic outcomes. Poor health can be expensive, because of the costs of treating illnesses. In addition, poor health can affect people's capacity to earn or save money *(58)*. This creates a cycle between poor health and poor household, local and national economic outcomes. At the same time, housing that is expensive relative to income can affect health, in particular for people on low incomes. High housing costs can compel people to cut back on other essentials that are connected to health, including food, energy and health care *(59–61)*. Difficulty with paying rent and mortgage costs exposes people to risks of eviction and foreclosure *(62)*, and increases the likelihood that people have to move often *(35, 63, 64)*. These factors – eviction, foreclosure and residential mobility – have each been associated with adverse educational and economic effects and poor health outcomes *(62, 65, 66)*.

Interventions that create healthy homes can help to break this cycle by improving health and broader social and economic outcomes, yielding important benefits for decades into the future. These housing-related interventions need to be complemented by policy interventions relating to education, employment, transport, child care, health systems, taxation, wages, benefit levels and job security. Each of these factors can affect incomes and thus affect people's ability to pay for housing that keeps them healthy *(27)*. Providing affordable housing can help people to afford housing that fits their needs while improving their health *(67, 68)*. Affordable housing, such as public housing, can be promoted through funding a supply of affordable dwellings, or through providing subsidies, such as housing vouchers or tax mechanisms (e.g. low-income housing tax credits) *(68, 69)*.



2

Guideline development process

2 Guideline development process

2.1 Contributors to the guidelines

2.1.1 WHO Steering Group

The WHO Steering Group (SG) has been involved in all stages of planning the HHGL, review of evidence and all rounds of consultation on revisions following peer review. Their inputs were provided through face-to-face meetings and email.

2.1.2 Guideline Development Group

The GDG was made up of people with content expertise in all areas covered by the HHGL, including relevant experience from low- and middle-income countries and expertise in evidence-based guideline development (see Acknowledgements for names and affiliations). GDG selection also took into consideration the need to ensure gender balance and regional diversity. The members of the GDG, under the guidance of the guideline methodologist, worked together to define key questions, priorities and systematic review methods, served as authors of HHGL chapters (including drafting and determining the strength of the recommendations), and responded to external peer review comments. Specified GDG members served as chair, co-chair and rapporteurs.

2.1.3 External Review Group

External reviewers were drawn from subject experts, implementing agencies and partners working on various aspects of policy to improve health outcomes related to housing to form the External Review Group (ERG) (see Acknowledgements for names and affiliations). External reviewers were asked to conduct a thorough peer review of the final guidelines' text and comment on the evidence reviews and the final recommendations.

2.1.4 Systematic review

Systematic reviews of the evidence on the effects of the prioritized interventions and exposures related to crowding, indoor temperature, accessibility and injury hazards were commissioned (see Acknowledgements for names and affiliations).

2.2 Identification of priority questions and critical outcomes

Following discussions with the GDG at the first meeting in Washington (DC) on 9–11 April 2013, a set of priority topics was identified for these guidelines. This took account of areas of healthy housing that have been covered in other, recent WHO guidelines in order to avoid unnecessary duplication. The priority topics demonstrated the need for a series of distinct systematic reviews of the effects of the relevant interventions or exposures: crowding, low indoor temperatures, insulation, high indoor temperatures, injury hazards, and housing accessibility. It was recognized that the breadth of the topics covered by these systematic reviews meant that different approaches would be needed, and that there would be relatively little, if any, overlap in their included studies and their conduct (e.g. search strategies). Therefore, a mixture of research groups was engaged to form the systematic review teams.

The questions to be addressed by each review were agreed by the WHO Secretariat, the SG and the GDG. These were converted into a PICO or PECO format to show the population, intervention (or exposure), comparator and outcome as the four elements to be considered in the systematic review of the evidence *(70)*. In order to focus the reviews, and their subsequent recommendations, the GDG prioritized the outcomes to be assessed. They ranked the relative importance of a series of health outcomes on a scale from 1 (not important for these guidelines) to 9 (critical) based on their own expert knowledge. The mean scores were calculated and the highest ranked outcomes for each review were included in its PICO or PECO.

2.3 Evidence identification and retrieval

Having agreed on the scope and eligibility criteria for each of the six systematic reviews, the systematic review teams, in consultation with the WHO Secretariat and guideline methodologist, used dedicated search strategies to systematically provide evidence on the effects of the prioritized interventions or exposures. The searches were conducted in 2015 and updated in 2018. GDG members and experts from the specific areas for each review were asked to suggest potentially eligible studies to help inform the design and implementation of the searches. Evidence on the effects of interventions (e.g. insulation and safety devices) stemmed mainly from randomized trials and non-randomized comparative studies (as necessary), while observational designs, such as case-control or cohort studies, were the most relevant designs for studies investigating the effects of exposures (e.g. crowding and heat).

The WHO Secretariat, designated members of the GDG and the methodologist worked together to develop the methods used for each review. The format for the reports of the systematic reviews was agreed with the WHO Secretariat, drawing on experience from previous systematic reviews for WHO guidelines. This included the inclusion of key elements for each review, such as the PICO or PECO used to define the scope of the review, the search strategy, methods, a table showing the characteristics of each included study and their quality, and an assessment of the overall quality of the evidence for the effects on each prioritized outcome using GRADE (Grading of Recommendations Assessment, Development and Evaluation) evidence profile tables (see the reviews for examples). A timeline was developed for the submission of the draft and final versions of the reviews to allow time for discussion with, and feedback from, the WHO Secretariat and members of the GDG.

Given the substantial differences in topic areas for the reviews, search strategies specific to each review were developed, tested and implemented by the systematic review teams. Details of these searches, including the number of retrieved records and the flow of these through the review process, are provided in the report for each systematic review.

2.4 Quality assessment and grading of the evidence

Each systematic review team used appropriate instruments to assess the quality and risk of bias of each study included in their review. This allowed a tailored approach to the quality assessment of the eligible studies for each review. It also allowed an overall assessment of the quality and relevance of the body of evidence for each review. Details of the methods used and the assessments are provided in the report of each review. The evidence gathered for the effects of an intervention or exposure on the prioritized health outcomes was assessed using the GRADE approach. This led to the categorization of the quality of evidence for each outcome as "high", "moderate", "low" or "very low", based on the risk of bias (and other quality features) in the included studies, along with inconsistency of results, indirectness, imprecision and other factors deemed relevant.

These assessments provided a starting point for the GDG when using the evidence on the health effects of interventions and exposures to develop the specific recommendations for the HHGL.

Where possible, the systematic reviews included information on potential disadvantages as well as advantages of the proposed interventions. This, along with the expert knowledge of the GDG, was used to incorporate information on the feasibility, harms, acceptability and cost–benefit considerations during the development of the recommendations.

The systematic reviews are available online at http://www.who.int/sustainable-development/publications/housing-health-guidelines/en/index.html.

2.5 Formulation of recommendations

The recommendations were formulated in two GDG meetings. The first took place face-to-face in Morges (Switzerland) on 13–15 July 2015, while the second took place by online video conference on 29 May 2018. The interval between the two meetings and the need for the second meeting was due to the time needed to assess the strength of the evidence as a whole, to update the systematic reviews and to draft the guidelines. For both meetings, the systematic reviews and GRADE evidence profile tables were shared with members of the GDG in advance. They were also discussed in preliminary teleconferences and other correspondence between the designated members of the GDG, the WHO Secretariat, systematic review teams and the methodologist. This led to the preparation of draft recommendations, which, together with the systematic reviews (in particular the summaries of evidence for the effects of the interventions or exposures on the prioritized health outcomes and the information on the quality of the evidence), were used by the GDG, WHO Secretariat and methodologist as a basis for discussing and agreeing the recommendations for each topic. The evidence from the systematic reviews was supplemented by the wide range and depth of experience across the GDG and, for instance, this information supported the assignment of the "trivial" categorization for the undesirable effects of some interventions, as detailed in the evidence to decision (EtD) tables.

The EtD framework for public health was used to derive and formulate the recommendations. Each recommendation was defined as either "strong" or "conditional", based on the relevant systematic review and evidence- and expert-opinion informed considerations of the balance between benefits and harms, values and preferences, equity, acceptability, feasibility and resource implications for the implementation of the recommendation. Strong recommendations communicate the message that they are based confidently on the evidence that the desirable effects of adherence to the recommendation outweigh the undesirable consequences. Conditional recommendations are less certain about the balance between the benefits and harms or disadvantages of implementing a recommendation.

The values and preferences of relevant stakeholders were taken into consideration when making the recommendations. This included considering the perspectives of both the private and public sectors involved in housing as well as the implications of the recommendations for individuals. The applicability and feasibility of the implementation of the recommendations in different geographical settings and countries with different income levels and housing needs and standards further influenced the formulation of recommendations. While the HHGL are global in nature, with the recommendations providing evidence-based guidance on how to ensure healthy housing, the GDG recognizes that not all recommendations will be implementable to the same extent and at the same time in all contexts. The implementation of the HHGL recommendations will require prioritization to best meet a country's most urgent needs, which can subsequently be expanded to longer term commitments to work gradually towards a full implementation.

The GDG also considered resource use, which was not a standard feature of the studies available in the systematic reviews of health outcomes, but was available in some cases *(25, 71)*. The GDG discussions covered the perspectives of members of the public who might be the individual payers for some interventions (e.g. smoke alarms, retrofitted house insulation, and home improvements for better accessibility), as well as governments, other parts of the public sector and the private sector who might be responsible for larger scale investments (e.g. to improve the housing stock generally) or actions (e.g. to introduce legislation around housing safety). Details of such considerations are provided in the EtD tables.

2.6 Decision-making during the GDG meetings

The technical consultations were guided by a preset protocol, allowing participants to discuss the draft recommendations where necessary; each of the pre-drafted recommendations was revised through group discussion. The final recommendations were agreed on unanimously by the GDG; only the recommendation on cold was adopted through a majority vote. Any concerns expressed about the adopted strength of a recommendation are noted in the guidelines. WHO staff, the guideline methodologist and observers at the meetings were not eligible to vote. If an issue to be voted upon involved research (including systematic reviews) conducted by any member of the GDG who had declared a conflict of interest, the members in question would be allowed to participate in the discussion, but excluded from the final vote on that particular issue.

2.7 Declaration of interests by external contributors

In accordance with WHO policy, all members of the GDG and ERG were required to complete and submit a WHO declaration of interest form. The WHO Secretariat, with support of the SG, reviewed and assessed the declarations submitted by each member and agreed on an approach to assess potential conflicts of interest.

A briefing was provided at the beginning of the first GDG meeting in Washington (DC) (April 2013) on the nature of all types of competing interests (i.e. financial, academic/intellectual and non-academic). Each member of the GDG was asked to discuss and declare to the meeting any conflicts they may have.

All appointed members of the GDG and the ERG completed the WHO declaration of interest forms and no conflicts of interest were declared.

2.8 Document preparation and peer review

The first draft recommendations from July 2015 were used as the basis for drafting the chapters of the HHGL. The draft chapters were prepared by the WHO Secretariat, designated members of the GDG and the methodologist, before being circulated to the GDG and the ERG as a whole for revision and approval. The WHO Secretariat used external reviewer comments to make suggested revisions to these initial drafts and further revisions and review took place of the revised draft in June 2018. The reviewers' comments and any suggested changes to the recommendations were then circulated to the GDG and SG for final agreement. No disagreement was expressed by reviewers.

3

Household crowding

3 Household crowding

Household crowding is a condition where the number of occupants exceeds the capacity of the dwelling space available, whether measured as rooms, bedrooms or floor area, resulting in adverse physical and mental health outcomes *(72, 73)*. Crowding is a result of a mismatch between the dwelling and the household. The level of crowding relates to the size and design of the dwelling, including the size of the rooms, and to the type, size and needs of the household, including any long-term visitors. Whether a household is "crowded" depends not only on the number of people sharing the dwelling, but on their age, their relationship and their sex. For example, a dwelling might be considered crowded if two adults share a bedroom, but not crowded if those adults are in a relationship *(74–76)*. Crowding relates to the conditions of the dwelling as well as the space it provides: people may crowd into particular rooms in their home to avoid cold or uninhabitable parts of the dwelling or to save on heating and other costs *(54)*.

The effects of crowding can be broadly defined as the hazards associated with inadequate space within the dwelling for living, sleeping and household activities *(77)*. Crowding is considered to be stressful to health and well-being across different cultures and aspects of life in low-, middle- and high-income countries *(78)*. Several studies have reported a direct association between crowding and adverse health outcomes, such as infectious disease and mental health problems. In addition, researchers have connected crowding to poor educational attainment *(79)*.

Worldwide, crowding is often a marker of poverty and social deprivation *(80, 81)*. It has been identified by the United Nations as one of five deprivations that suggest an informal settlement should be characterized as a slum *(82)*. Crowded households are also often exposed to housing risks discussed in other chapters in the HHGL. For example, the income constraints that compel people to live in dwellings with inadequate space for their needs *(78)* can also mean that such households struggle to afford housing that is in good repair or to heat homes sufficiently *(83, 84)*. In addition, crowding increases exposure to risk factors associated with home injury, social tensions and exposure to second-hand tobacco smoke (SHS) *(85, 86)*.

In order to establish clear guidance on minimizing the health risks associated with crowding, a systematic review of the evidence was commissioned.

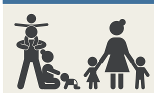
Question for the systematic review

In the general population exposed to household crowding, what is the exposure-response relationship between exposure to crowding and the proportion of persons with poorer health compared with the population not exposed to household crowding?

The systematic review focused on the following priority health outcomes:

- close-contact infectious diseases
- gastroenteritis and diarrhoeal diseases
- mental health, including psychological stress
- sleep disturbance.

3.1 Guideline recommendation

Recommendation	Strength of recommendation
 Strategies should be developed and implemented to prevent and reduce household crowding.	Strong

Remarks

- Each Member State should choose an appropriate way to measure the amount of crowding in a household, including a threshold that can be used to define a household as "crowded".
- Implementing agencies can draw on a range of existing measures of crowding (also described as "overcrowding") to determine a measure appropriate to their context (see Table 3.1). Specific guidance exists for emergency shelters *(87)*.[4]
- While the prevalence of infectious diseases varies between countries, the evidence of an association between crowding and adverse health effects is such that implementing agencies should work to reduce crowding regardless of the local prevalence of specific infectious diseases.

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[4] Following United Nations High Commissioner for Refugees (UNHCR) standards, emergency shelters located at public buildings are recommended to have 4.5–5.5 m^2 per evacuee (refugee) in cold climates, as residents remain inside the shelters during daytime *(87)*.

Table 3.1 Measures of crowding

UN-Habitat
Overcrowding occurs if there are more than three people per habitable room *(88)*.
American Crowding Index
Crowding occurs if there is more than one person per room; severe crowding occurs if there are more than 1.5 persons per room (excluding bathrooms, balconies, porches, foyers, hall-ways and half-rooms) *(89)*.
Argentinian National Institute of Statistics and Censuses
Overcrowding represents the quotient between the total number of people in the home and the total number of rooms or pieces of the same *(90)*. Households with critical overcrowding are considered those with more than three people per room (excluding the kitchen and bathroom) *(91)*.
Canadian National Occupancy Standard
Overcrowding occurs if extra bedrooms are required to ensure that each of the following have their own bedroom: • cohabiting adult couple • lone parent • unattached household member aged 18 years or over • same sex pair of children aged under 18 years • each additional boy or girl in the household (unless there are two opposite sex children under 5 years, in which case they can share a bedroom) *(75)*.
British Bedroom Standard
Overcrowding occurs if extra bedrooms are required to ensure that each of the following have their own bedroom: • cohabiting adult couple • person aged over 21 years • same sex pair of children aged 10–20 years • two children aged less than 10 years • two children where one is aged 10–20 and one is aged less than 10 years • any other person aged under 21 years that is not paired under one of the preceding categories *(76)*.
Eurostat
Overcrowding occurs if the household does not have at its disposal a minimum number of rooms equal to: • one room for the household • one room per couple in the household • one room for each single person aged 18 years or more • one room per pair of single people of the same gender between 12–17 years • one room for each single person between 12–17 years and not included in the previous category • one room per pair of children under 12 years *(74)*.

- The certainty of the evidence relating to TB and other respiratory infectious diseases was assessed as **high**. The certainty of the evidence relating to gastroenteritis and diarrhoeal diseases, other infectious diseases and to mental health was assessed as **moderate to high.** The certainty of the evidence relating to sleep disorders was assessed as **low**.
- Having considered the certainty of the evidence, the balance of benefits to harms related to reducing crowding, the values and preferences associated with reducing crowding, and the feasibility of reducing crowding, the GDG made a **strong** recommendation.

3.2 Summary of evidence

This section summarizes the evidence from the systematic review on the association between crowding and infectious diseases (including TB, gastroenteritis and diarrhoeal diseases), mental health (including stress) and sleep disorders. The definitions and measures of crowding in the included studies varied and were, for example, based on persons per room, rooms per house, square meterage of living space per person, or living in single or multiple rooms.

The systematic review and the GRADE tables used to present the certainty of the evidence are available online at http://www.who.int/sustainable-development/publications/housing-health-guidelines/en/index.html in Web Annex A.

3.2.1 Infectious diseases

When interpreting the following results, it needs to be considered that the relationship between crowding and infectious diseases depends on the background prevalence of the disease in the specific setting.

Tuberculosis (TB)
Much of the research on the association between crowding and infectious diseases concerns TB.

Twenty-one studies – ten case-control *(92–101)*, eight cross-sectional *(102–109)*, two ecological *(112, 110)* and one retrospective cohort *(111)* – were identified that related crowding to TB. These studies were consistent in showing that crowding is associated with increased risks of TB, even though the positive association was not statistically significant in a small number of the studies.

Four studies investigated the effect of different levels of crowding on the incidence of TB *(98, 99, 104, 106)*. In these studies, increasing numbers of persons per room were analysed in relation to the incidence of TB. One of these found a significant increase for two to four persons/room in comparison with one person/room but not at greater than four persons/room *(104)*, while the other three studies did not show a statistically significant relationship between increased crowding and the incidence of TB (greater than one and half, greater than two, one to three, three to five persons per room) *(98, 99, 106)*. In the two studies that examined an exposure-response relationship for crowding and TB, one found a consistent relationship *(112)*, but the other did not *(99)*. The 15 other studies used a threshold for crowding, comparing crowded with non-crowded households. Although crowding was not found to have a statistically significant association in four studies *(92, 95, 97, 105)*, crowding was significantly associated with TB in each of the other 11 studies *(93, 94, 96, 100–103, 107, 108, 110, 112)*.

The certainty of the evidence that reducing crowding would reduce the risk of TB was assessed as **high.**

Respiratory diseases (excluding TB)

Thirty studies reporting on outcomes due to respiratory infectious diseases other than TB were included in the systematic review. These investigated flu-related hospitalizations and illnesses: seven studies *(113–119)*; pneumonia: six studies *(120–125)*; acute respiratory illness: 16 studies *(126–141)*; and respiratory syncytial virus: *(142)*. The study designs included 14 cross-sectional, six case-control, five cohort (including a randomized trial in which the intervention was not related to housing, which was an incidental variable) and five ecological studies.

Across the majority of studies on non-TB respiratory diseases, the risk of acquiring the diseases was associated with crowding.

The certainty of the evidence that reducing crowding would reduce the risk of non-TB respiratory disease was assessed as **moderate to high,** depending on the disease**.**

Diarrhoea and gastroenteritis

Thirteen studies – two case-control *(143, 144)*, seven cross-sectional *(145–151)* and four cohort *(152–154, 475)* – were identified that related crowding to diarrhoea or gastrointestinal diseases or parasites, showing that crowding appears to be associated with gastroenteritis and diarrhoeal diseases. Among the included studies, four looked at the effects of different levels of crowding *(145, 147, 148, 155)*. In two of the studies, the higher levels of crowding (greater than three or four people per room) were associated with significantly more cases of diarrhoea compared with the lower levels (less than two or four people per room) *(147, 153)*. In two studies, the level of crowding did not significantly affect the number of cases of diarrhoea, but in one of these studies all levels of crowding were associated with the surrogate outcome of increased intestinal parasite infection *(145)*.

The certainty of the evidence that reducing crowding would reduce the risk of gastroenteritis and diarrhoeal diseases was assessed as **high.**

Other infectious diseases

Twenty-five studies investigated an association between crowding and other infectious diseases such as rheumatic fever and heart disease: five studies *(156–160)*; typhoid fever: one study *(161)*; meningococcal disease: seven studies *(162–168)*; throat eye and skin infections: three studies *(137, 169, 170)*; dengue fever: one study *(171)*; *Helicobacter pylori*: one study *(172)*; methicillin-resistant *Staphylococcus aureus*: two studies *(173, 174)*; parasite *Toxoplasma gondii*: one study *(175)*; Epstein Barr virus: one study *(176)*; neonatal infections: one study *(177)*; multi-drug non-susceptible enteric infections: one study *(178)*; and risk factors for WASH: one study *(179)*. Study designs included ten cross-sectional, nine case control, one ecological and five cohort studies. In general, the risk of acquiring the infectious diseases was associated with crowding.

The certainty of the evidence that reducing crowding would reduce the risk of other infectious diseases was assessed as **moderate to low,** depending on the disease**.**

3.2.2 Non-infectious health disorders

Mental health including stress

Of the 13 separate studies in this category (one of which assessed two different mental health outcomes), eight studies reported at least one significant association between household crowding and the mental health outcome. A prospective cohort study *(180)*, a retrospective cohort study *(181)* and five cross-sectional studies *(182–186)* all reported that participants living in a crowded household were more likely to report a mental health problem than those not living in crowded conditions. These mental health concerns included: psychological distress, alcohol abuse, feeling depressed and feeling unhappy about one's health. One cross-sectional study further found that crowding was associated with a lower prevalence of psychiatric disability *(187)*.

Four cross-sectional studies could not detect any relationship between crowding and mental health outcomes such as inattention-hyperactivity and emotional symptoms *(130)*, psychological distress *(188)*, suicidal ideation and self-esteem *(189)*, or drug abuse *(186)*. Further, one retrospective cohort study carried out in Israel reported no association between crowding during infancy and development of schizophrenia in later life *(190)* and one cohort study conducted in the United States of America found no link between overcrowding and autonomic nervous system reactivity or externalizing behaviour problems *(474)*.

The certainty of the evidence relating crowding to adverse mental health effects, including stress, was assessed as **moderate to low.**

Sleep disorders

Two recent cross-sectional *(191, 192)* and one ecological study *(193)* investigated the associations between crowding and sleep disorders. One cross-sectional study found excessive daytime sleepiness with greater than one per room *(192)* but the other study concluded that living in a crowded household (greater than or equal to one per room) is not significantly associated with most outcomes relevant to sleep disturbance but did find a significant relationship between crowding and duration of sleep in some analyses *(191)*.

The ecological study found a significant positive relationship between percentage of neighbourhood-level crowding (greater than one per room) and the apnoea–hypopnoea index *(193)*.

The certainty of the evidence that reducing crowding would reduce the incidence of sleep disorders was assessed as **low to very low.**

In summary, the systematic review found high certainty evidence that crowding is associated with an increased risk of TB and diarrhoea. There is moderate to high certainty evidence for a positive relationship between crowding and other respiratory infectious diseases. The certainty of the evidence that crowding is associated with an elevated risk of other infectious diseases and poor mental health is moderate to low; and very low for the linkage between crowding and sleep disorders.

3.3 Considerations for implementation of the guideline recommendation

Reducing crowding has implications for national and local governments, which usually need to build and refurbish housing, subsidize social or public housing, regulate private rental housing, implement tax and planning policies that encourage the building of affordable housing, and work with community leaders in informal settlements. Ensuring housing that is not only available, but also appropriate and affordable, is crucial to reducing crowding. If reducing crowding entails people moving to another location, it might have detrimental effects by removing them from social networks, child care support, and work or educational opportunities, affecting health and earning opportunities *(194, 195)*. If new housing is situated in low-density or sprawling developments, it can reduce physical activity *(196, 197).* If new housing is not affordable, people may have difficulty paying for other essentials including food, energy and health care *(59)*. Therefore, an integrated policy approach, in which reductions in crowding are supported by appropriate rehousing that takes these considerations about potentially unintended effects into account, is fundamental to equity. Reductions in crowding will be most effective if combined with policies that support employment and improve household incomes to increase the affordability of homes with sufficient space. A supportive social welfare system further ensures that loss of job or other income shock does not entail moving into a dwelling with inadequate space in order to reduce costs.

When developing policies to reduce crowding, policy-makers and technical advisors also need to consider the relevance of crowding measures to different subpopulations *(78)*. Depending on the cultural context, an inhabitant's perception of an overcrowded home might vary and different standards to determine adequate housing space might apply. Table 3.1 provides an overview of different crowding measures that can be applied to assess the prevalence and level of crowding in different settings.

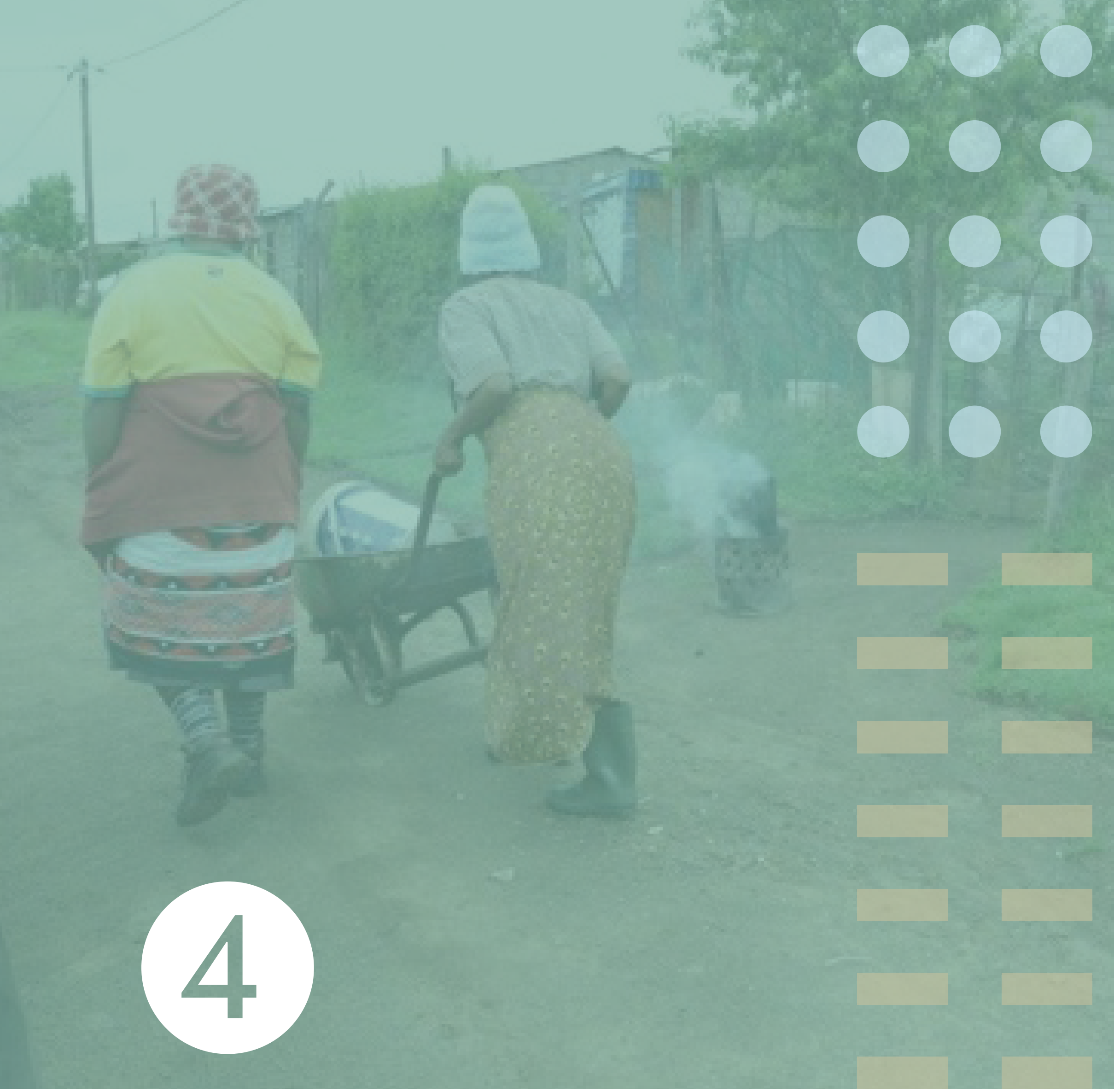
3.4 Research recommendations

The research reviewed shows that crowding is associated with negative health outcomes. However, the study designs, and the close association between social deprivation and crowding, caution against the attribution of causation. The research base could be further strengthened through focusing on the research priorities shown in Table 3.2.[5]

Table 3.2 Research recommendations: crowding

Current state of the evidence	Although there is good evidence on the association between crowding and poor health outcomes, most studies to date are observational and there is considerable heterogeneity in their design. Meta-analysis is difficult because studies define crowding differently, focus on different outcomes and subgroups of interest, and have used different approaches to adjust (or not) for confounding. Further high-quality studies are required, including randomized trials and comparative studies, perhaps using cluster randomized designs. Such studies might test the impact of new housing policies intended to reduce overcrowding, and subsequent effects on health outcomes. Future research should also examine the exposure-response relationships between crowding and health outcomes, including mental health outcomes and intellectual development of children, and make adjustments for confounding. In order to help others to compare, contrast and combine the results of different studies, researchers should use standard and internationally recognized measures of crowding and common approaches to recording and reporting outcomes.
Population of interest	Populations living in residential housing. There is a particular need to understand the effects of crowding on different subpopulations (in particular men, women, children, the elderly, indigenous and at-risk populations).
Interventions of interest	Policies and interventions to reduce crowding, including through extending existing homes, through rehousing and policies that support employment and improve household incomes.
Comparisons of interest	Groups living in crowded and non-crowded home environments; groups before and after interventions to reduce crowding. It is also important to compare the effect on health of people living in different levels of crowding (i.e. "crowding" as opposed to "severe crowding") and people living for different lengths of time in crowded housing (exposure-response relationships).
Outcomes of interest	Key outcomes of interest are TB and other infectious diseases, gastroenteritis and diarrhoeal diseases, sleep quality, intimate partner violence and mental health.
Time stamp	Current systematic review included studies published up to April 2018.

[5] All research recommendations in these guidelines are presented using the EPICOT framework. This summarizes key components of research recommendations under six headings: state of the **E**vidence; **P**opulation; **I**nterventions; **C**omparisons; **O**utcomes (or Outputs); **T**ime st amp.



4

Low indoor temperatures and insulation

4 Low indoor temperatures and insulation

Cold air inflames lungs and inhibits circulation, increasing the risk of respiratory conditions, such as asthma attacks or symptoms, worsening of chronic obstructive pulmonary disease (COPD), and infection. Cold also induces vasoconstriction, which causes stress to the circulatory system *(198)* that can lead to cardiovascular effects, including ischaemic heart disease (IHD), coronary heart disease, strokes, subarachnoid haemorrhage and death *(198–206)*. Most of the evidence for the impact of cold on health comes from studies connecting outdoor temperatures to health outcomes. For example, cold spells are associated with increased mortality and respiratory and cardiovascular morbidity *(207)*, and mortality and morbidity rates in countries with cold and temperate climates are higher in winter than in summer *(208)*.

Evidence that cold indoor temperatures have adverse consequences for health is growing *(209, 210)*. Cold indoor temperatures are often a consequence of outdoor temperature, structural deficiencies, including a lack of insulation and airtightness, and lack of heating. As outlined in this chapter, cold indoor temperatures have been associated with increased blood pressure, asthma symptoms and poor mental health. Cold homes contribute to excess winter mortality and morbidity. Most of the health burden can be attributed to both respiratory and cardiovascular disease, especially for older people. In children, the excess winter health burden is mostly due to respiratory disease. Excess winter deaths due to cold housing has been estimated at 38 200 per year (12.8/100 000) in 11 selected European countries *(18)*.

Winter mortality is greater in countries with milder climates than in those with more severe winter conditions *(211)*, in part because countries with mild winters often have homes characterized by poor domestic thermal efficiency that are harder to heat than well insulated houses in more extreme climates. In insulated dwellings, thermal insulation reduces conductive heat loss through the buildings' walls, ceilings and floors. Retrofitted insulation, otherwise known as "weatherization" also reduces convective heat loss by blocking unwanted air leaks through the building envelope. As outlined in this chapter, retrofitted insulation, weatherization, and heating can help mitigate the effect of otherwise cold housing on health.

Socioeconomic factors play an important role in determining whether a dwelling is sufficiently warm. Income constraints force people to live in housing that is older, more likely to be poorly built and lacking insulation. These deficiencies, in addition to lack of energy affordability, can make it especially difficult for people on low incomes to heat their houses adequately. For example, a study carried out in South Africa showed that informal dwellings were more vulnerable than other types of dwellings to indoor temperature instability, which affected thermal comfort *(212)*.

In order to assess the evidence on minimizing the health risks associated with cold indoor temperatures and the effects of insulating houses, two systematic reviews were commissioned.

Question for the first systematic review (exposure)
Do residents living in housing where indoor temperatures are below 18 °C have worse health outcomes than those living in housing with indoor temperatures above 18 °C? The categorical cut-off point at 18 °C was chosen based on the conclusions of a previous WHO working group on indoor environment finding that "there is no demonstrable risk to human health of healthy sedentary people living in air temperature of between 18 and 24 °C" *(213)*.

The systematic review focused on the following priority health outcomes, as ranked by the GDG:

- respiratory morbidity and mortality
- all cause-mortality in infants
- hospital admissions
- cardiovascular morbidity and mortality
- depression.

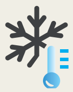
Question for the second systematic review (intervention)
Do people living in housing with insulation have better health outcomes than those living in housing without insulation?

The systematic review focused on the following priority health outcomes, as ranked by the GDG:

- respiratory morbidity and mortality
- cardiovascular morbidity and mortality
- hospital admissions

- all cause-mortality
- depression
- high blood pressure.

4.1 Guideline recommendations

Recommendation		Strength of recommendation
	Indoor housing temperatures should be high enough to protect residents from the harmful health effects of cold. For countries with temperate or colder climates, 18 °C has been proposed as a safe and well-balanced indoor temperature to protect the health of general populations during cold seasons.	Strong
	In climate zones with a cold season, efficient and safe thermal insulation should be installed in new housing and retrofitted in old housing.	Conditional

Remarks

- There is an association between cold indoor temperatures and adverse health effects, and an association between retrofitting insulation in housing and improved health outcomes. Implementing agencies should work to increase temperatures in cold homes, including through installing insulation with appropriate ventilation, as this is likely to have beneficial effects on health.
- While current evidence is insufficient to establish the precise temperature below which adverse health effects are likely to occur, there is high certainty that taking measures to warm cold houses will have significant health benefits and a minimum of 18 °C is widely accepted.
- A higher minimum indoor temperature than 18 °C may be necessary for vulnerable groups including older people, children and those with chronic illnesses, particularly cardiorespiratory disease *(213)*.
- The GDG assessed the certainty of the evidence to indicate the extent to which the research supports the recommendation. The certainty of the evidence that warming a cold house reduces the risk of cardiovascular disease is **moderate** (based on the findings for blood pressure). The certainty of the evidence that installing insulation is associated with improved health outcomes is **high** but this is qualified by different types of insulation.

- Having considered the certainty of the evidence, the values and preferences associated with indoor thermal condition, the balance of benefits to harm related to increasing indoor temperatures and installing insulation, and the feasibility of taking these measures, the GDG made a **strong** recommendation regarding cold and a **conditional** recommendation regarding insulation.

4.2 Summary of evidence

This section summarizes the systematic reviews of the associations between indoor cold and health outcomes, and the benefits to health of thermal insulation in the home environment. The systematic reviews on indoor cold and on insulation against cold and the GRADE tables used to assess the certainty of the evidence are available online at http://www.who.int/sustainable-development/publications/housing-health-guidelines/en/index.html in Web Annex B and Web Annex C.

4.2.1 Respiratory morbidity and mortality

Of the four studies identified in the systematic review, three found that colder indoor temperatures increased respiratory morbidity. One cross-sectional study in adults with COPD found better health status with more hours of indoor temperature at and above 21 °C. A dose-response trend was observed for number of days with bedroom temperatures of 18 °C and above for at least 9 hours. The greatest effects were observed in adults who smoked compared with non-smokers *(214)*. Similarly, modelling based on the results of a randomized trial involving children with asthma found that every 1 °C increase in room temperature below the threshold of 9 °C, was associated with a small but significant increase in lung function. Bedroom exposure was shown to have stronger association with asthmatic children's lung function than living room exposure *(215)*. In addition, one cohort study, including adults with COPD, from China reported reduced respiratory problems with an indoor temperature at 18.2 °C regardless of whether indoor humidity was low, moderate or high *(216)*. In contrast, a case-control study in children with and without upper respiratory tract infections showed no consistent associations with indoor temperature *(217)*.

The certainty of the evidence that warming a cold house (perhaps to a minimum indoor temperature of 18 °C) would reduce the risk of respiratory mortality and morbidity was assessed as **moderate.**

4.2.2 Cardiovascular morbidity and mortality: blood pressure

Of the six included studies that assessed the association between indoor temperature and blood pressure, all showed that lower temperatures were associated with higher blood pressure, including two randomized trials in Japan that found higher blood pressure in people living in colder homes *(218, 219)*.

A cohort study in Japan of adults over 60 years of age found that decreases of 1 °C in indoor temperatures were significantly associated with increased blood pressure levels at different times of the day, even after controlling for potential confounders *(220, 221)*. There was a stronger association of indoor temperature than outdoor temperature with ambulatory blood pressure, which suggested that excess winter cardiovascular mortality could be prevented by improving the housing thermal environment *(221)*. Two cohort studies from Scotland found people in housing heated to less than 18 °C had a greater risk of high blood pressure *(222, 223)*. This risk increased if temperatures were below 16 °C (OR 4.92) *(223)*. Similarly, a cohort study in the United Kingdom found a decrease in systolic and diastolic blood pressure of 0.5 mmHg per 1 °C increase in room temperature *(224)*.

The review also identified five studies of temperature and blood pressure that were done under laboratory conditions *(225–229)*. The studies show a relationship between warming and lower blood pressure but, because this is indirect evidence for the relationship between blood pressure and housing indoor temperature, the studies were not used in formulating the recommendations.

The certainty of the evidence that warming a cold house (to a minimum indoor temperature of 18 °C) would reduce the risk of cardiovascular mortality and morbidity was assessed as **moderate.**

4.2.3 Insulation and weatherization

Of the 11 studies identified in the systematic review, seven found some association between the benefits of living in an insulated home and improved health. For example, a cluster randomized trial in New Zealand on the effect of insulating existing homes where at least one person in the household had existing chronic respiratory symptoms found that insulation was associated with reduced odds of poor mental health, self-reported wheezing in the previous 3 months, winter colds or flu, and morning phlegm in adults *(39)*.

While mental health was improved in one controlled trial from the United States of America, the study did not find any differences in general health status between people receiving new insulation and exterior cladding and those in the control group *(230)*. One quasi-experimental study from the United Kingdom found no difference between asthmatic and healthy children with regard to different glazing systems *(231)*. Another quasi-experimental study in New Zealand found that all-cause mortality was significantly lower in people with a history of cardiovascular disease if they lived in an insulated rather than an uninsulated house and non-significantly lower in people with a history of respiratory disease *(232)*. Similarly, a controlled trial from the United Kingdom did not detect any effect of external insulation on general respiratory symptoms, asthma, physical or mental health or subjective well-being *(233)*.

A cross-sectional study from the United Kingdom investigated the effects of different types of insulation on a range of health outcomes *(234)*. The study identified positive effects of loft and external wall insulation on respiratory, mental and general health; but found a negative impact on these outcomes with cavity wall insulation.

Three retrospective cohort studies investigated the effects of living in an insulated home on health. A New Zealand study of 45 000 households, with matched controls, showed no relationship between living in an insulated home and rates of hospitalization. However, mortality rates for adults aged 65 and over who had previously been hospitalized for circulatory illness were lower for people living in insulated dwellings *(235)*. A study from Scotland, looking at the indoor environment and health outcomes as reported by participants, found that rates of coughing were significantly lower in homes with double-glazed windows but no consistent relationship between wheezing and coughing, and insulation *(236)*. A study from Greenland, of households with children aged 3 to 5 and 8 years who had a previous medical attendance for acute otitis media, found no relationship between episodes of acute otitis media and self-reported poor insulation, defined as "reports of draft along the floors and through doors and windows" *(237)*. A historical cohort study conducted in the United Kingdom reported that double glazing improved the household health status by 4.8% but did not detect effects on quality of life or other measures of well-being *(238)*.

One case-control study from Denmark, which had a high risk of bias, found that eye irritation and throat dryness (connected to respiratory health) decreased slightly when windows were replaced, but the results were not statistically significant *(239)*.

The certainty of the evidence that living in insulated homes is associated with improved health outcomes was assessed as **moderate.**

4.3 Considerations for implementation of the guideline recommendations

In a cold climate, a healthy indoor thermal environment can be achieved through a combination of thermal insulation and heat supply. Building a properly ventilated and thermally insulated house is more technically advanced and expensive than building a non-insulated house, but is likely to lead to health and other benefits, with some evidence that the cost–benefit ratio can be as high as six *(232)*. On a macro-level, improving energy efficiency of dwellings was found to lead to cost savings and in some countries the clear co-benefits of retrofitted insulation on health and energy efficiency mean that these retrofits are already subsidized by governments. For example, it is estimated that improvements in occupants' health by improving housing in the United Kingdom, including through increasing warmth in bedrooms, would save the United Kingdom health services £1.4 billion in the first year in treatment costs alone *(240)*. An insulation subsidy programme in New Zealand found reduced hospitalization costs due to fewer re-admissions, fewer transfers and shorter stays in hospital, although the rate of hospitalization was unchanged *(40)*. In Cape Town, retrofitting of 2300 houses with solar water heating and roof insulation as part of the Kuyasa low-income housing project had multiple benefits for climate mitigation, respiratory health, poverty reduction, and economic development *(241)*. Besides generating 2.82 tonnes of carbon credit per house annually and lowering heating expenditures, the improved insulation led to a "substantial decline in bronchial and related illness among residents, especially during winter" *(241)*. More broadly, energy efficiency measures contribute to public savings by reducing the burden on energy infrastructure and the climate. Insulation can also help moderate extreme heat situations, as discussed in Chapter 5. Yet, cost–effectiveness will vary significantly for different climate zones and depends on housing quality, the type of insulation, the prior level of insulation and means of heating and ventilation of the housing stock.

At an individual level, there is a clear trade-off between investment costs (installing or retrofitting insulation and heating) and running costs (paying for energy). While people with low incomes are likely to benefit the most from public thermal efficiency programmes because they are more likely to live in cold homes *(52)*, they will also be less likely to be able to afford to install insulation if the costs need to be covered by the inhabitants or home owners. Therefore, it is essential to ensure that low-income people can afford to live in improved buildings, potentially through providing public support for housing costs; otherwise improvements in insulation might increase inequities *(242)*.

Key instruments for policy-makers to improve thermal conditions at national level are: improving building standards and mandating insulation and efficient heating in housing, including the installation of solar panels, implementing subsidies and tax incentives to encourage the installation of insulation and efficient heating; measures to encourage energy affordability through subsidizing or replacing traditional energy costs; and the building of replacement housing where housing is in such disrepair that it cannot be renovated to a standard that ensures adequate temperatures.

To avoid unintended harms of installing insulation, care must be taken to ensure that measures to improve the warmth of dwellings also provide adequate ventilation. Ventilation standards for housing are available from several organizations, such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62 *(243)* and in Europe, the standards of the Buildings Performance Institute Europe *(244)*. Weatherization reduces heat loss via air leaks through walls and ceilings, but it can also reduce the necessary air exchange of the building. Household activities, including cooking and washing, as well as human metabolism, generate water vapour. Without adequate ventilation, either natural or mechanical, dampness accumulates inside the building. Insufficient airflow increases indoor humidity, leading to an increase in dampness and growth of mould and bacteria *(245)*. Dampness or mould is associated with a range of adverse health effects, including asthma, respiratory infections and symptoms, dyspnoea, hypersensitivity pneumonitis and allergic alveolitis *(246)*. Guidance regarding indoor air quality, including in relation to mould, is available from WHO and summarized in section 8.2.

It is critical that any intervention to increase the indoor temperature is achieved through sustainable and energy effective solutions. Installing insulation and efficient heating can contribute to the reduction of carbon emissions by enabling people to heat their homes more efficiently. This reduces air pollution and indirectly benefits health through reducing mortality and morbidity associated with outdoor air pollution. These measures also reduce the burden on energy infrastructure and support climate change mitigation *(39)*.

Implementation also needs to consider the importance of using safe insulation materials, which are free of toxic substances such as asbestos and isocyanate, and are resistant to fire and microbial growth. Improved occupational safety and health protection and training for those involved in installing and maintaining thermal insulation may also be required to ensure that the health of workers is not compromised and that the intervention will be optimally effective *(247)*. Authorization of the building retrofit designers and approval/inspection of the actual work are necessary to ensure healthy and energy efficient results.

4.4 Research recommendations

The specific mechanisms underlying the association between cold homes, lack of insulation, and poor health may involve both physiological responses or co-exposures to other associated factors causing adverse health problems, such as damp, mould, poor quality housing, poverty and social deprivation. Further research is needed to investigate these associations and underpin the research priorities summarized in Tables 4.1 and 4.2 for the exposure (cold) and for the intervention (insulation).

Table 4.1 Research recommendations: cold

Current state of the evidence	While there is good evidence associating low indoor temperatures with adverse health outcomes, further studies, especially in developing countries and particularly in Africa, are required which assess exposure-response associations while controlling for potential confounders (including outdoor temperature). These should take into account peak (occasional low temperatures), chronic (extended periods of low temperatures) and cumulative exposure *(215)*.
Population of interest	The whole population; in particular, people that are both more likely to spend time at home and experience adverse health effects related to cold (e.g. the elderly, children, and people with long-term illnesses). Studies are required to establish whether 18 °C is the most appropriate general target for the minimum indoor temperature and whether the minimum target should vary across different population groups.
Interventions of interest	Policies and interventions to increase indoor temperatures to healthy levels, including through installing insulation, weatherization, and improved heating, including through alternatives such as solar panels, through subsidies and market-based initiatives *(248)*.
Comparisons of interest	Groups living in home environments in cold climates that are not heated to an adequate temperature and those that are; groups before and after intervention.
Outcomes of interest	A range of health outcomes should be included, including indoor temperature and mortality and morbidity, and cardiovascular disease, asthma, COPD, infections and depression.
Time stamp	Current systematic review on the association between indoor cold and health outcomes included studies published up to April 2018.

Table 4.2 Research recommendations: insulation

Current state of the evidence	The evidence base on the effects of living in an insulated home on health outcomes should be strengthened through further high-quality studies, including randomized trials. These studies should control for confounding factors, including outdoor temperature, ventilation, and the availability, affordability and efficiency of heating. Research should prioritize professional, independent assessment of insulation levels and health outcomes over self-reports by occupants.
Population of interest	The whole population; in particular, people that are both more likely to spend time at home and experience adverse health effects related to cold (e.g. the elderly, children, and people with long-term illnesses), who may particularly benefit from insulated housing.
Interventions of interest	Installing insulation, and the introduction of market-based initiatives intended to encourage the installation of insulation.
Comparisons of interest	Groups living in insulated and non-insulated home environments; groups before and after intervention.
Outcomes of interest	Indoor temperature and relative humidity and change in air exchange rates, plus a range of health outcomes. These include indoor temperature and mortality and morbidity; in particular, cardiovascular disease, asthma, COPD, infections and depression.
Time stamp	Current systematic review on the association between insulation and health outcomes included studies published up to April 2018.

5

High indoor temperatures

5 High indoor temperatures

High temperatures and temperature variations harm health. Human response to heat is dependent on the body's ability to cool itself *(249)*. An important cooling mechanism is perspiration and its evaporation from the skin and, therefore, because high air humidity can reduce and eventually prevent net evaporation, the health effects of high temperatures depend also on relative humidity (or more precisely the dew point temperature of air). High outdoor temperature is associated with thermal discomfort *(250)* and adverse health outcomes, including higher rates of all-cause and cardiovascular mortality and emergency hospitalizations, across a range of study designs and across geographical regions *(251–255)*. Children, the elderly, and those with psychiatric, cardiovascular and pulmonary illnesses have a weaker physiological response to heat, and are more vulnerable to the negative impact of high temperature on health *(249, 256–258)*.

Public health interest in the effects of heat on health has grown recently in part because of climate change and the increasing frequency and duration of heat waves across all continents *(6)*. For example, the May 2010 heat wave in Ahmedabad, India, was associated with significant excess all-cause mortality: 4462 all-cause deaths occurred, meaning an estimated 43.1% increase when compared with the reference period with 3118 deaths *(259)*. It is further estimated that an excess of 70 000 people in 16 countries across Europe died in August 2003 due to a major heat wave *(260)*. Across Africa, the frequency (spatial coverage) of extreme heat waves has increased to 24.5 observations per year (60.1% of land area) between 2006 and 2015, as compared with 12.3 per year (37.3% of land area) in the period from 1981 to 2005 *(261)*. People who live in temperate climates are more likely to be affected by high temperatures; the temperature threshold where heat-related deaths begin to increase during a heat wave is lower in cities with cooler climates *(262, 263)*. Exposure to heat waves earlier in the season has a greater impact on mortality, because the population has not had a chance to adapt to higher temperatures *(264)*.

The importance of acclimatization (i.e. physiological adaptation to excessive heat exposure) is stressed in the WHO-World Meteorological Organization (WMO) guideline for heat wave warning systems, but complete acclimatization to an unfamiliar thermal environment may take several years. Long-term adaptation results in a lower rise in core body temperature and a lower increase in heart rate at a given heat load *(265)*. In addition, while people may adapt to usual temperatures, they may not be able to adapt to variable temperatures. Unstable temperatures harm the cardiovascular and immune system, and are associated with an increase of mortality *(266)*.

Studies have shown an association between high indoor temperatures and adverse health effects *(267)*. Outside of regions where air conditioning is common, high indoor temperatures are associated with high outdoor temperatures. In a case cross-over study carried out in three Latin America cities, same and previous day apparent temperatures were strongly associated with mortality risk, with susceptibility increasing with age *(268)*. Therefore, studies of morbidity and mortality rates during periods of high outdoor temperatures can also be used to provide indirect evidence of the harmful health effects of high indoor temperatures in such regions. For example, during the 2003 heat wave in France, the number of deaths at home was considerably higher compared with years without extreme heat events *(269)*. In Japan, a study showed that heatstroke most often occurs at home during summer; elderly people developed heatstroke in their homes with greater frequency compared with patients in other age groups *(270, 271)*. In summary, given that people spend most of their time indoors *(2)* and that, in the absence of air conditioning, they will be exposed to an increased risk of high indoor temperatures during periods of high outdoor temperature, protection against outdoor heat is a key characteristic of healthy housing.

Air conditioning, insulation, certain building materials, wall thickness, shading from direct sunlight, natural ventilation (especially during night time), and increased air motion (fans) to cool indoor temperatures can help protect people against heat and heat-related illness. However, large numbers of people in developing countries, as well as low-income groups in developed countries, do not have access to such housing facilities. As a consequence, low socioeconomic groups are at higher risk of heat-related mortality *(249, 264)*. Research carried out in São Paulo, Brazil, for example, showed that those with less education were more susceptible to heat-related mortality *(268)*. Air conditioning can also reinforce health inequalities by exacerbating urban noise and heat, which negatively affect the health of others, particularly those who cannot afford air conditioners. Air conditioning contributes to climate change, with knock-on effects on health, due to heavy energy consumption and use of powerful greenhouse gases as coolants.

In order to establish clear guidance on minimizing the health risk associated with high indoor temperatures, a systematic review of the evidence was commissioned.

Question for the systematic review

Do residents living in housing where indoor temperatures are above 24 °C have worse health outcomes than those living in housing with indoor temperatures below 24 °C? The categorical cut-off point at 24 °C was chosen based on the conclusions of a previous WHO working group on indoor environment finding that "there is no demonstrable risk to human health of healthy sedentary people living in air temperature of between 18 and 24 °C" *(213)*.

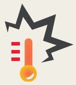
The systematic review focused on the following priority health outcomes:

- all-cause mortality
- heatstroke
- hyperthermia
- dehydration
- hospital admission.

The systematic review is available online at http://www.who.int/sustainable-development/publications/housing-health-guidelines/en/index.html, along with the GRADE tables used to assess the certainty of the evidence in Web Annex D. Additional analysis conducted to provide indirect evidence to support the recommendation regarding high indoor temperatures is also available online. This looked at the likely effect of high indoor temperatures on health but did not specifically address temperatures of above 24 °C.

The review identified six studies that included indoor dwelling temperature as an exposure variable. However, none of these studies provided direct evidence on the prioritized health outcomes or the minimal risk temperatures for heat-related health effects. Therefore, no firm answer can be given to the question of whether people living in housing with a temperature above 24 °C have worse health outcomes than those living in housing with an indoor temperature below that threshold.

5.1 Guideline recommendation

Recommendation		Strength of recommendation
	In populations exposed to high ambient temperatures, strategies to protect populations from excess indoor heat should be developed and implemented.	Conditional

Remarks

- Identification of the minimal risk temperature for heat-related health effects will require research to determine the indoor temperature below which no adverse health effects related to heat are expected. Likewise, research is needed to identify the "maximum acceptable temperature", above which the risk to human health increases drastically. As people are acclimatized to different temperatures in different climate regions, the optimal indoor temperature range is dependent on the specific region. Examples of minimal risk temperature for heat-related health effects and maximum acceptable temperature are listed in Table 5.1, drawing on the analysis set available at http://www.who.int/sustainable-development/publications/housing-health-guidelines/en/index.html.
- There is an association between high indoor temperatures and some adverse health effects. Implementing agencies should work to reduce indoor temperatures to the minimal risk temperature, because this is likely to have beneficial effects on health. It is particularly important to keep the indoor temperature of the housing of vulnerable individuals, such as the elderly, infants, sick and the disabled, below the maximum acceptable temperature.
- The GDG assessed the certainty of the evidence to indicate the extent to which the research on each health outcome supports the recommendation. As there are so few studies of the direct effect of high indoor temperature on health, the certainty of the evidence that reducing high indoor temperatures would reduce morbidity and mortality was assessed as **low to very low**. However, there is higher certainty of evidence that there is a relationship between high indoor and high outdoor temperatures and that high outdoor temperatures are associated with morbidity and mortality.
- Therefore, having considered the certainty of this range of evidence on high temperature and health, the balance of benefits to harms of preventing exposure to high indoor temperature, the values and preferences associated

with preventing exposure to high indoor temperature, and the cost and feasibility of preventing such exposure, the GDG made a **conditional** recommendation.

Table 5.1 Examples of estimated minimal risk temperature for heat-related health effects and maximum acceptable temperature

City/country	Indoor minimal risk temperature for heat-related health effects	Indoor maximum acceptable temperature
Boston (United States of America)	21–22 °C	25 °C
New York (United States of America)	22–24 °C	27–28 °C
London/Manchester (United Kingdom)	22–23 °C	~25 °C
Harbin (China)	~24 °C	26 °C
Republic of Korea	~25–26 °C	~29–30 °C
Thailand	~30 °C	~32 °C

5.2 Summary of evidence

The systematic review on the association between high indoor temperatures and adverse health outcomes identified eight eligible studies. Further, indirect evidence to support the association between high indoor temperatures and adverse health outcomes was identified in the following manner:

- Step 1: Studies on health and outdoor temperature were reviewed to obtain estimates of the relationship between outdoor temperature and health outcomes.
- Step 2: Studies that measured both indoor and outdoor temperature were reviewed and used to model the association between indoor and outdoor temperatures. This association was used to derive indoor temperature based on the outdoor temperature.
- Step 3: An assumption was taken that the estimates derived in Step 1 would equally apply to the indoor temperatures calculated in Step 2. These were used to support the recommendations regarding high indoor temperatures.

5.2.1 Temperature and morbidity

Indoor temperature and morbidity

Eight studies investigated the effect of indoor heat on health outcomes including, sleep disorders (three studies); general health, blood pressure, respiratory and cardiovascular disease (two studies each); and body temperature, mental health, pregnancy outcomes (one study each).

One quasi-experimental study of 57 people in the United States of America found that reductions in number of days above 27 °C corresponded with improved quality of health and life, reduced emotional distress and increased hours of sleep *(272)*.

Three cohort studies explored the association between indoor heat and morbidity. While there were no associations between indoor temperatures and reports of respiratory viral infection or heat illness in a cohort of 40 households in the United States of America, the same study found a significant relationship in sleep problems and prior day's temperature in the summer season but not in winter *(273)*. Similarly, among 113 elderly people in the Netherlands, an increase of 1 °C of indoor temperature raised the risk of sleep disturbance by 24% (in the temperature range of 20.8 to 29.3 °C) *(274)*. A third cohort study, in Slovenia, reported worse cardiovascular symptoms with a higher heat burden and low indoor air quality *(275)*.

One case series involving 20 low-income elderly people in the Republic of Korea and one cohort study including 132 women in India, found a non-significant positive relationship between indoor temperature and systolic blood pressure but a significant positive association with diastolic blood pressure *(276, 277)*.

A case-control study reported that humidity exposure and indoor heat above 26 °C non-significantly increased the proportion of emergency calls in New York that were due to cardiovascular cases and respiratory distress calls *(278)*.

Finally, a cross-sectional study among 1136 women in Ghana found a non-significant increase in adverse pregnancy outcomes, such as stillbirth or miscarriage, with each additional 1 °C increase in atmospheric heat exposure *(476)*.

In view of the mixed findings and the relatively small amount of evidence, the certainty of the direct evidence that reducing high indoor temperatures would reduce morbidity or mortality was assessed as **low.**

Outdoor temperature and morbidity

In order to help with the discussions in the GDG, analyses were also done of the effects of outdoor temperature, for which studies on the association between high temperature and morbidity show a non-linear temperature-effect relationship. For example, associations between daily average temperatures and the relative risk estimates for hospital admissions for kidney disease are U-shaped (admissions occur in both the lower and higher temperature ranges) or J-shaped (admissions occur in the higher temperature ranges). Temperatures at around 25 °C present the lowest risk for hospital admission for kidney disease, and high temperatures increase the risk of admission more than low temperatures *(254)*. Although heat waves are significantly associated with elevated risk of cardiovascular hospitalizations *(279)*, recent meta-analysis indicated no apparent association between increased ambient temperature and cardiovascular morbidity *(255, 280)*.

The certainty of this evidence linking high outdoor temperature with increased morbidity was assessed as **low to moderate** and, although indirect, it was used in conjunction with the evidence on the relationship between outdoor and indoor temperature to provide support for the recommendation on indoor temperatures.

5.2.2 High temperature and mortality

High indoor temperature and mortality

No eligible studies assessed the effect of high indoor temperature on mortality.

High outdoor temperature and mortality

Reviews and meta-analyses provide strong evidence of the association between high outdoor temperature and mortality *(251, 252, 264, 279, 281)*. There is a non-linear temperature-mortality effect relationship, with U- or J-shaped curves for temperature-mortality relationships for all-cause mortality categories *(282)*; J-shaped curves for cardiovascular disease mortality *(283)*; J-shaped curves for non-accidental, cardiorespiratory and cardiovascular mortality as cumulative effects of diurnal temperature range; and U-shaped for respiratory mortality, with strong monotonic increases at a diurnal temperature range of approximately 16 °C *(284)*.

The exposure-response curve helps to identify a minimal risk temperature above which mortality increases as temperature increases *(249)*. The minimal risk temperature extends up to 31 °C for different cities in low- and middle-income countries *(262)*. It averages 29.4 °C in Mediterranean cities, and 23.3 °C in northern continental cities *(285)*. The optimal outdoor temperature for health varies considerably across populations, depending on climate and socioeconomic profile *(263, 281)*. The mortality risk due to high and low temperatures varies from roughly the 60th percentile of the location-specific temperature range in tropical areas to the 80–90th percentile in temperate regions, which is equivalent to 19 °C in Stockholm, Sweden, and 30 °C in Bangkok, Thailand *(281)*.

The certainty of the evidence relating high outdoor temperature to mortality was assessed as **high**, and, although indirect, it was used in conjunction with the evidence on the relationship between outdoor and indoor temperature to provide support for the recommendation regarding indoor temperatures.

5.2.3 Relationship between indoor and outdoor temperature

Thirty-two studies were identified which reported the relationship between indoor and outdoor temperature. These showed a positive correlation in the higher temperature range (>20 °C). The slope of a linear regression between outdoor and indoor temperatures in the warm/hot temperature range (>20 °C) varied depending on several factors including air conditioning, ventilation, insulation, building direction, socioeconomic status and the behaviour of the occupants.

Most of the studies were conducted in temperate climate zones. The studies show that the slope of the correlation curves between indoor and outdoor temperatures in this climate zone was usually not steep, which may be due to the influence of air conditioning in some dwellings *(286)* and the practice of keeping the windows closed rather than opening them for ventilation *(287)*. Specific cities have unique correlation curves *(288, 289)*. Some studies are better able to predict indoor temperatures from outdoor temperatures by incorporating other environmental factors into a multivariate regression. These factors include urban heat islands affecting the immediate environment *(290)*, solar radiation *(291, 292)* or dwelling characteristics *(293)*. The relationship between indoor and outdoor temperatures depends on the socioeconomic status of the participants with indoor temperatures of the dwellings of low-income residents more closely associated with outdoor temperatures because they are not influenced by the use of air conditioners *(276, 294)*. Indoor and outdoor temperatures are also more closely correlated where the occupants opened their window for ventilation *(295)*.

Fewer studies have been done in subtropical regions, but these also suggest relationships between indoor and outdoor temperatures. In low-income countries, where air conditioning is seldom available, indoor temperature is directly related to outdoor temperature *(296–298)*. The relationship becomes weaker further away from the equator *(299, 300)*. There is no relationship between indoor and outdoor temperature in countries where air conditioning is widely available everywhere, such as Oman *(301)*. One study found that the indoor temperature could be higher than the outdoor temperature due to cooking activities and inadequate ventilation *(302)*.

The certainty of the evidence that indoor and outdoor temperatures are correlated was assessed as **moderate to high**, and this indirect evidence was used in conjunction with the evidence on the relationship between high outdoor temperatures and adverse health outcomes to provide support for the recommendation regarding indoor temperatures.

5.3 Considerations for implementation of the guideline recommendation

Thermal insulation, housing location, building materials and house orientation, window shades, green spaces and ventilation (including use of cooler night-time air) and air conditioning can help to mitigate high indoor temperatures *(303)*. Improved ventilation and air conditioning have helped decrease the relative risk of heat-related mortality in the United States of America, Japan and Spain over the past two decades *(304)*.

However, air conditioning is not always feasible because of implementation and running costs. Increased reliance on mechanical air conditioning has a disadvantage in that it increases costs, energy consumption and carbon emissions. Furthermore, poor maintenance of air conditioning can create health problems, due to mould, lack of condensation drainage and circulation of airborne pollutants. Therefore, passive mitigation measures or mechanical ventilation systems that are free or low-cost to run, such as those powered by solar technology, are often preferable. World Health Organization guidance on natural ventilation measures in health care settings may also be relevant to housing *(305)*.

Member States can support measures to cool housing through regulations on minimum requirements for ventilation, insulation and air conditioning measures through subsidies to support such measures, and through building codes that emphasize the importance of maximizing thermal comfort; and through planning codes that acknowledge the importance of urban design, such as urban forests, shading, wind management and green roofs, in keeping cities cool.

Public health authorities should develop and activate heat wave warning systems, as stipulated in the WHO-WMO guidance, and should prepare for extreme heat events *(265)*. In addition, public awareness campaigns can increase understanding of the harms associated with heat exposure. This includes encouraging people to engage in cooling behaviours at home, such as taking showers and remaining hydrated *(306)*, to counter the negative health effects of indoor heat.

5.4 Research recommendations

Some of the evidence summarized in this chapter is indirect, based on the association between indoor and outdoor temperatures, and the association between high outdoor temperatures and health outcomes. However, there is great variation between outdoor and indoor temperatures in terms of the types of heat exposure (direct or indirect sun), the types of activity typically carried out, and the possible interactions with other risk factors associated with housing, including humidity, housing conditions, socioeconomic conditions, the type of structure (including insulation), ventilation/air conditioning, and outside temperature. Further research should therefore focus on the direct effects of high indoor temperatures on health.

Table 5.2 Research recommendations: high indoor temperature

Current state of the evidence	Few high-quality studies have assessed the direct effects of indoor temperature on health. The current research base is limited by a lack of data on indoor household temperature and the difficulty of designing studies capable of entirely excluding the health impact of outdoor temperatures. High-quality studies that control for confounders are required. These should focus on exposure-response associations and take into account peak (occasional high temperatures), chronic (extended periods of high temperatures) and cumulative exposure.
Population of interest	The whole population; in particular people who are both more likely to spend time at home and experience adverse health effects related to heat (the elderly, children, women, obese people, and people with long-term illnesses). Studies across different groups will help establish whether the threshold level (the temperature above which temperature poses a risk to health) is different for different population groups.
Interventions of interest	Installing ventilation and other measures aimed at reducing indoor temperature in housing in hot climates; and moving people to cooler housing in hot climates.
Comparisons of interest	Groups living in hot climates in home environments at different temperatures; groups before and after interventions to reduce indoor temperatures.
Outcomes of interest	A range of health outcomes should be included, including mortality and morbidity generally, but, in particular, cardiovascular disease, blood pressure, respiratory symptoms, sleep disturbance, heatstroke, hyperthermia, dehydration.
Time stamp	Current systematic review on the direct association between high indoor temperatures and health outcomes included studies published up to April 2018. The literature review to provide evidence on the indirect relationship between high indoor temperatures and health was done by members of the GDG in April 2016.

6

Injury hazards

6 Injury hazards

Injuries in the home present an important health burden worldwide *(307)*. Globally, around a third of injuries occur in the home *(308)*, and, in 2016, half of all unintentional injury-related deaths occurred in the home *(309)*. Although injuries in the home affect people of all ages, home injury rates are highest in the youngest and oldest age groups *(310)*. They are also more common in people with functional impairment and interventions to improve their housing conditions are discussed in Chapter 7.

Injuries in the home include falls, burns, poisonings, ingestion of foreign objects, smoke inhalation, drowning, cuts and collisions with objects, and crushing and fractured bones as a result of structural collapse. This chapter focuses on injuries caused by hazards that can be eliminated or controlled with proper attention to housing design and maintenance *(311)*.

Falls account for the largest proportion of the injuries in the home that require medical attention *(56)*. Worldwide, about 424 000 individuals die each year from falls, of which the vast majority are in low- and middle-income countries, and more than 37 million falls require medical attention *(312)*. In Thailand, for example, almost 70% of severe injuries related to accidental falls occur in the home or residential areas *(313)*. Similarly, falls are the leading cause for hospital admissions due to injuries in Fiji *(314)*. In India, the rate of deaths from falls in urban areas, including the home, was 15.6 per 100 000 in 2005 *(315)*. In high-income countries, about 26% of falls can be attributed to the environment, both inside and outside the home. In low- and middle-income countries, about 31% of falls are attributable to the environment *(316)*. Hazards that encourage slips and falls that could result in injuries include: uneven floor surfaces; inadequate or inappropriate lighting; steep stairs, stairs of varied height, stairs without handrails or in disrepair; lack of guarding of stairs, landings and balconies; lack of grab-rails or handles to baths and showers; and windows and doors without child safety locks *(317–319)*. In Europe, in 2010, around 10 deaths (0.007 per 100 000) and 3310 DALYs (2.0 per 100 000) were attributable to a lack of window guards (that is, bars and other products that prevent people falling from windows) *(18)*.

The home environment can also put people at risk of injury and death from burns. Injury from exposure to heat, fire and hot substances results from hazards such as an absence of smoke detectors, unsafe electric installation, open fires, unprotected hot surfaces and hot water. Around 268 000 deaths occur each year worldwide due to burns from exposure to fire, heat or hot substances, including in the home environment *(49)*. In the developing countries of Africa, Asia and Latin America, kerosene use for cooking and lighting remains widespread, with fires and explosions being well-documented kerosene hazards *(320)*. More specifically, in one hospital in Sri Lanka, 41% of patients admitted for burns had been injured by falling kerosene lamps *(321)*. In Bangladesh, the overall burn mortality rate was 2.2 per 100 000 in 2003, with 90% of burn incidences occurring in the home mostly caused by cooking fire, heating fire and fire from kerosene lamps *(322)*. In Europe, 7523 deaths (0.9 per 100 000) and nearly 200 000 DALYs (22.4 per 100 000) are attributable to a lack of smoke detectors *(18)*. Nearly a quarter of scald burns in children in the United States of America were caused by hot tap water *(319)*. Unvented gas or solid fuel burning stoves also expose people to dangerous levels of carbon monoxide (discussed in Chapter 8).

Injury rates at home are sometimes higher for low-income people *(323)*. This is partly because homes that contain hazards are more likely to be within the price range of people with low incomes. For example, a United States of America survey reported that fire extinguishers, fire escape plans and carbon monoxide alarms were much less common in low-income homes *(310)*. In Thailand, severe injuries are more common for unskilled labourers than other population groups *(313)*; and in Kenya, a low level of education was identified as a key risk factor for burn injury among patients admitted to a public hospital *(324)*. Reducing hazards in homes can therefore contribute to reducing health inequalities *(325, 326)*. And, a study carried out in Nigeria, South Africa, Uganda and the United Republic of Tanzania found that living in an urban environment was associated with increased odds for injury *(327)*.

In order to establish clear guidance on minimizing the health risk associated with hazards in the home, a systematic review of the evidence was commissioned.

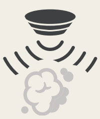
Question for the systematic review
Do residents in housing with fewer hazards have fewer injuries than residents living in housing with more hazards?

The systematic review focused on the following priority health outcomes, as ranked by the GDG:

- electrocution
- broken or fractured bones
- mortality due to injuries
- burns or scalds
- hospitalization (outpatient or inpatient) due to injuries.

Although it was recognized that injuries due to building collapse are an important health issue; the focus for these guidelines was on hazards present within the house.

6.1 Guideline recommendation

Recommendation		Strength of recommendation
	Housing should be equipped with safety devices (such as smoke and carbon monoxide alarms, stair gates and window guards) and measures should be taken to reduce hazards that lead to unintentional injuries.	Strong

Remarks

- There is strong evidence for an association between hazards in the home and injuries. Implementing agencies should work to reduce the number of hazards in housing, because reducing these hazards is likely to have beneficial effects on health.
- In addition to increasing the risk of burn injuries, fireplaces and fuel-burning appliances can contribute to poor health outcomes and poor indoor air quality. WHO guidelines around household fuel combustion are summarized in section 8.2.
- The GDG assessed the certainty of evidence to indicate the extent to which the research on each intervention supports the overall recommendation, and, in general, the certainty of the evidence for reducing hazards in the home is **moderate to high**. In relation to specific safety devices and safety measures, the certainty of the evidence that reducing fire hazards (through

installing smoke detectors) reduces the risk of burns is **moderate**. The certainty of evidence that the use of guards to protect against fires and hot surfaces reduces the risk of burns is **low to moderate**. The certainty of the evidence that installing stair gates and window guards reduces the risk of falls is **low to moderate**. The certainty of the evidence that home safety modification programmes reduce the risk of injury is **moderate**.

- Having considered the certainty of the evidence, the balance of benefits to harm of modifying the home to prevent home injury, and the values, preferences and feasibility of doing so, the GDG made a **strong** recommendation.

6.2 Summary of evidence

The recommendations were informed by a systematic review of the evidence on the exposure-response relationship between housing factors and injury. The systematic review and the GRADE tables used to assess the certainty of the evidence are available online at http://www.who.int/sustainable-development/publications/housing-health-guidelines/en/index.html in Web Annex E.

6.2.1 Smoke detectors

Properly installed and functioning smoke alarms were found to reduce the incidence of burn injuries. A randomized trial in the United States of America found that burns and fires in the homes were prevented by smoke alarms and carbon monoxide detectors at baseline and at 12 and 24 months' follow-up *(328)*.

A Canadian case-control study found an increased risk of burns and scalds in children if their house did not have a smoke alarm *(329)*. Similarly, a case-control study in Iraq found that, among children admitted to hospital, there were fewer smoke alarms in the homes of those who had sustained a burn injury *(330)*. Another study, in the United Kingdom, reported that among children seeking primary care, admitted to hospital, or presenting to the emergency department, those with burn injuries were less likely to have working smoke alarms in the home *(331)*. However, another case-control study, in the United States of America, reported that burn cases had similar rates of smoke alarm usage and use of carbon monoxide detectors *(332)*.

The evidence that smoke alarms reduce the risk of hospitalization is supported by two additional cohort studies. One found that the introduction of legislation for compulsory smoke alarm ownership in an Australian state decreased hospitalization rates by 36.2% annually *(333)*. The other found that fire-related death and injury were lower in the population with an installed smoke alarm than in the population without a smoke alarm *(334)*.

The certainty of the evidence that the presence of smoke detectors reduces the risk of injury was assessed as **moderate.**

6.2.2 Stair and safety gates

Three studies reported on the effects of stair or safety gates on injury in children. A cohort study in the United Kingdom found that among children under 5 years of age, those who lived in homes that had been fitted with stair safety gates were less likely to be admitted to hospital, to attend primary care or to access the accident and emergency department *(331)*. A case-control study in Bangladesh found that children living in homes where the kitchen did not have a door were more likely to sustain burns *(335)*. This finding is supported by a case-control study from the United Kingdom, in which not using safety gates was associated with a significant increase in scalds *(336)*.

The certainty of the evidence that installing stair and safety gates reduces the risk of injury was assessed as **low to moderate.**

6.2.3 Window guards

One cross-sectional study from the United States of America assessed the effect of window guard legislation. Window guards were found to be twice as effective in preventing falls than windows without guards *(337)*.

The certainty of the evidence that window guards reduce the risk of injury was assessed as **low to moderate.**

6.2.4 Fireplace guards, stoves and unprotected hot surfaces

Three studies investigated the effects of fireplace and stove guards on injury. A case-control study in the United States of America found that people admitted to hospital to treat burns were likely to use fireplace guards less often than the control group *(332)*. In contrast, a cohort study from the United Kingdom found no association between fire guard use and burn injuries *(338)*. A Canadian case-control study reported an increased risk for burns or scalds when there was no stove guard to prevent children from grabbing pots *(329)*.

Other studies have looked at how the presence of specific lamps or heaters affects the risk of injury. A case-control study in the Islamic Republic of Iran found that the odds of burn injury were twice as high in homes with unvented air heaters rather than conventional vented kerosene- or gas-burning heaters *(339)*. A pre-post intervention study in India found that the number of unintentional burns was reduced to zero from 23 among 1042 households in the 6 months after kerosene lamps were replaced with solar or LED lamps *(340)*. In the Bangladesh case-control study, burns were more likely in children in the presence of a traditional kerosene lamp *(335)*, and a case-control study in Iraq found that people who had been burned or scalded were more likely to use kerosene heaters for space heating *(330)*.

The certainty of the evidence that guarding against fireplaces, stoves and dangerous unprotected hot surfaces reduces the risk of injury was assessed as **low to moderate.**

6.2.5 Home safety modification programmes

Five randomized trials studied the effect of home safety assessment and modification programmes on injuries *(26, 328, 341–343)*. These had mixed results depending on the comparator for the home safety assessment and modification programmes, some of which are effective interventions for, for example, reducing falls. However, in general, people living in homes in which hazards had been reduced were less likely to sustain injuries than those who received no injury prevention interventions. For example, a randomized trial in New Zealand of adults over 75 years who had severe visual impairments found that there were fewer falls in the group of participants in the home safety programme, compared with those who did not receive this programme *(341)*. Similarly, a randomized trial in the United States of America showed that the rate of medically attended injuries was reduced in children who had the programme compared with controls who did not *(328)*. This is supported by Keall et al. (2015), who found that medically treated falls were rarer for the group of dwellings that had been assessed and modified for safety *(26)*. And a randomized trial from Japan found that falls occurring in the home 1 year after introducing a home hazard modification programme were reduced more in the intervention group than in the control group *(343)*. In contrast, a randomized trial of older adults in the United Kingdom found that the home modification programme did not reduce the incidence of falls *(342)*.

The certainty of the evidence that home safety modification programmes reduce the risk of injury was assessed as **moderate**.

6.2.6 Association between the number of hazards in the home and the incidence of injuries

Four case-control studies found a dose-response relationship between the number of home hazards and the need for medical consultations or visits to health care services. A New Zealand study reported an estimated increase of 22% in the odds of injury occurrence associated with each additional home injury hazard *(326)*. A Canadian study of adults aged 65 years and over found that an increase in the number of home hazards was associated with an increased risk of a second fall-related medical visit *(344)*. While at the other end of the age spectrum, a study of children (aged 9 months to 3 years) in the United Kingdom found that those who lived in homes without any of the four hazards measured (no fire guard, safety gate, smoke alarms and electric socket covers) were approximately 20% less likely to have been injured than those with all four hazards *(338)*. Finally, a study that compared residents in a high fall rate building and a low fall rate building in Florida, United States of America, found fewer environmental hazards in the low fall rate building *(345)*.

In addition, several other studies investigated the association between single hazards such as slippery floors, uncovered furniture corners or a lack of grab bars in the shower *(345–352)*, with the majority of studies finding a positive relationship between the presence of hazards in the home and unintended injuries.

The certainty of the evidence that a higher number of hazards in the home is associated with an increased risk of injury was assessed as **moderate to high**.

While many injury prevention interventions have been tested in high-income settings, the GDG deems the suggested prevention measures generalizable to middle- and low-income countries. This is because injuries have certain antecedents. For example, burns are caused by excessive heat. Similarly, injury prevention has certain universal interventions applicable to all contexts, e.g. burns can be prevented by smoke alarms.

6.3 Considerations for implementation of the guideline recommendation

Several tools are available to help assess and improve home safety. These include housing-based health risk assessment methodologies such as the English Housing Health and Safety Rating System, the United States National Healthy Housing Standard, or the New Zealand Rental Warrant of Fitness (developed from the Healthy Housing Index) *(242, 353–355)*. Using such checklists relevant to local housing type, including adapting these to low-income settings and a variety of housing environments, can help prioritize interventions and ensure that serious hazards are not ignored or overlooked *(356, 357)*.

Taking action to reduce hazards in the home can be efficiently carried out alongside housing improvements that address other risk factors covered by these guidelines. One key instrument in reducing hazards in housing is mandated requirements, accompanied by effective enforcement measures. Measures should be put in place to ensure that codes rapidly integrate injury and building science. In addition, subsidies and tax incentives can encourage safety modifications. Such measures can be supported by education campaigns to teach the public what they can do to reduce the risk of injury in the home *(358)*.

Reducing injury hazards in the home is likely to provide considerable health benefits, particularly for the poorest people, children, the elderly, the disabled and other at-risk populations living in the lowest quality housing. This action is likely to be cost-effective because the benefits from fewer injury-related hospitalizations have been shown to be larger than the costs of improving home safety, resulting in net benefits *(26, 71, 359–366)*. Housing that is in such a state of disrepair that it cannot be modified may have to be demolished. Therefore, implementing this HHGL recommendation will probably need to be accompanied by the provision of new low-income housing to avoid potentially inequitable consequences.

6.4 Research recommendations

The research reviewed suggests that interventions aimed at reducing hazards in the home are associated with positive health outcomes, but there are continuing uncertainties about the size of the benefits and the impact of specific interventions. The research base would be strengthened by focusing on a number of priorities.

Table 6.1 Research recommendations: injury hazards

Current state of the evidence	Some studies were not included in the review because they assessed multicomponent interventions, making the effect of home structure modification on health outcomes difficult to distinguish from other interventions to decrease injuries (such as behaviour change). Future studies might consider using factorial designs to enable analyses of the effects of the specific interventions that make up a multicomponent intervention in different locations. These need to be large enough to have adequate power to detect the effect on different outcomes. In addition, more research is needed to assess the exposure-response relationship between the number and type of hazards, the amount of time spent in the home, and the frequency and magnitude of injury.
Population of interest	The whole population, in particular, people from low- and middle-income countries and those both more likely to spend time at home and experience adverse health effects due to injury (e.g. the elderly, children, women and people with long-term illnesses).
Interventions of interest	Reducing injury hazards in housing, including through installing safety devices and removing hazards.
Comparisons of interest	Groups living in home environments where home modifications aimed at reducing the risk of injury have been carried out and where home modifications have not been carried out; and groups before and after such interventions.
Outcomes of interest	Injuries, including electrocution, broken or fractured bones, mortality due to injuries, burns or scalds, and hospitalization (outpatient or inpatient) due to injuries.
Time stamp	Current systematic review on the association between hazards in the home and injury included studies published up to April 2018.

7

Housing accessibility

7 Housing accessibility

Disability is an umbrella term describing physical or psychological impairments, activity limitations or participation restrictions *(367)*. At least 1 billion people, or 15% of the world's population, have some form of disability *(368)*. The disabled population is increasing as the world's population ages *(369)*. Disability disproportionately affects low-income households, and has a higher prevalence in low- and middle-income countries *(368)*. Disability can cause and contribute to poverty *(368)*. People with functional impairment are more likely to be discriminated against when looking for housing, and more likely to pay high costs for housing relative to their income *(370)*.

According to the United Nations Convention on the Rights of Persons with Disabilities, Member States have an obligation to identify and eliminate all barriers to accessibility, including in housing *(371)*.

As functioning and disability result from an "interaction between the person's health condition and both personal and environmental factors" *(372)*, contextual factors substantially determine whether an impairment is perceived as disabling. Accessible dwelling can improve a person's domain-specific functioning within their home. Life span housing (also known as life cycle housing, lifetime homes or adaptable housing) can accommodate changes in human functioning over a person's life span, enabling the occupants to remain in their homes as long as possible. Universal design (or universal housing) is an approach to the design, construction and adaptation of housing to meet the needs of all occupants regardless of their age, functioning or social situation *(373)*.

Most homes are not currently built with accessibility in mind. For example, only about one fifth of public buildings in Enugu city, Nigeria, were found to be accessible for wheelchair users *(374)*. However, there is a high chance that they will be occupied by people with disablities at some time, especially considering the trend of ageing populations. In the United States of America, it has been estimated that there is a 60% probability that any new house will be occupied by a person with a functional impairment over its life span *(375)*. Non-accessible home environments expose people with functional impairments to risk of falls and injuries, restricts social participation, negatively affects quality of life, and increases the burden on caregivers and external social services *(376, 377)*. They limit a person's ability to manoeuvre in different spaces.

In order to establish clear guidance on maximizing the health gains associated with accessible housing, a systematic review of the evidence on the effects of home improvements for people with functional impairment was commissioned.

Question for the systematic review
Do residents with functional or cognitive impairments living in accessible/usable home environments have better health/social outcomes than residents with functional or cognitive impairments living in conventional or unmodified home environments?

The systematic review focused on the following priority health outcomes, as ranked by the GDG:
- injury rates (especially falls)
- well-being/quality of life
- mental health/depression
- dependency on external social or care services
- social participation.

7.1 Guideline recommendation

Recommendation	Strength of recommendation
 Based on current and projected national prevalence of populations with functional impairments and taking into account trends of ageing, an adequate proportion of the housing stock should be accessible to people with functional impairments.	Strong

Remarks
- People with functional impairments living in accessible home environments have better health and are better able to accomplish everyday tasks and manage living independently than those living in conventional or inaccessible home environments. Implementing agencies should work to ensure that people with functional impairments live in accessible housing, because this is likely to have beneficial effects on health. The

recommendation is limited to the effect of housing accessibility on people with functional impairments because of the small number of studies focusing on people with cognitive impairments.

- Each implementing agency should determine what percentage of the housing stock is required to be "adequate" to meet the needs of the population with functional impairments. They should do this by considering current and projected national prevalence of people with functional impairments and trends in ageing. A good discussion on estimation methods is available *(378)*. The level required for "adequate" provision will need to be reviewed as the population changes; in particular, as it ages. Given that accessible housing is not exclusively occupied by people with functional impairments, it is likely that the proportion of accessible housing stock would be higher than the proportion of households that include people with functional impairments.
- Implementing agencies can draw on a range of existing programmes that target an increase in the supply of accessible dwellings.
- The GDG assessed the certainty of the evidence to indicate the extent to which the research supports the recommendation and, in general, the certainty of the evidence for interventions to improve the accessibility and usability of the houses of people with functional impairment is moderate, supporting the decision to provide a strong recommendation. This overall certainty arises from a consideration of the accumulated evidence as a whole, which suggests important benefits for this disadvantaged population even though the evidence is of low certainty for some interventions and outcomes. In relation to specific aspects of the findings from the systematic review and other information, the certainty of the evidence that people with functional impairments are better able to accomplish activities of daily living when living in accessible environments was assessed as **low to moderate;** the certainty of the evidence that people with functional impairments are less likely to fall and be injured when living in accessible environments was assessed as **moderate;** the certainty of the evidence that living in accessible environments reduces the mortality rate of people with functional impairments was assessed as **low;** and the certainty of the evidence that people with functional impairments experience positive psychological effects and improved quality of life when living in accessible environments was assessed as **low to moderate**.
- Having considered the certainty of the evidence, the balance of benefits to harm related to increasing the supply of accessible dwellings, and the

feasibility of increasing the supply of accessible dwellings, the GDG made a **strong** recommendation.

7.2 Summary of evidence

This recommendation was informed by a systematic review of the evidence on the impact of accessible housing on residents with functional or cognitive impairments. The systematic review and the GRADE tables used to assess the certainty of the evidence are available online at http://www.who.int/sustainable-development/publications/housing-health-guidelines/en/index.html in Web Annex F.

Twenty studies, including six randomized trials, were eligible for the systematic review. Almost all the studies focused on people with functional impairments, with only one study of people with cognitive impairments *(379)*. Interventions implemented to enhance home accessibility features were carried out either as a sole intervention or as part of a multicomponent programme. Home modifications were mainly focused on architectural changes or fitted devices (such as grab bars) targeting mobility issues. Some focused on lighting improvements or adjustments targeting vision.

7.2.1 Activities of daily living

Functional impairments are often operationalized in terms of whether a person can accomplish activities of daily living (ADL) or instrumental activities of daily living (IADL). IADL refers to basic tasks of everyday life such as bathing, dressing, transferring, toileting, continence and feeding. ADL refers to a range of activities that are required for independent living in the community, such as preparing meals, housekeeping, taking medication, shopping, managing one's own finances, travelling and using the telephone.

Some studies reported the effects of interventions on ADL/IADL related outcomes. Three studies reported considerable decreases in perceived difficulties performing ADL/IADL after home modifications *(380–382)*; but difficulty with mobility/transfer did not change *(382)*. Self-efficacy, which was defined as confidence in managing difficulty, was improved in one intervention group *(382)*. Increased safety with ADL/IADL was also identified 2 months after home modifications among adults with impairments. The greatest safety benefits were in regard to bathroom use and entry access *(380)* and to difficulty in bathing and toileting *(382)*. In addition, one population-based survey identified a strong association between self-recognized difficulty managing ADL and perceived unmet needs for home accessibility features among people with physical impairments, after adjusting for the severity of their physical limitations *(383)*. This suggests that people who already have difficulties functioning in everyday life can benefit from home accessibility features, possibly delaying further deterioration of their functioning.

One randomized trial involving people with visual impairments did not identify a significant improvement overall in self-rated certainty in performing specific activities 6 months after lighting adjustments *(384)*. In addition, two studies found no significant change in dependence with ADL/IADL at 2 months and up to 9 months after home modifications *(380, 385)*, although it was noted that dependence in bathing was significantly decreased between 2 to 3 months and 8 to 9 months after home modifications *(385)*. These non-significant findings may be because the participants were elderly meaning that the participants' functions declined so rapidly that specific home modifications had an effect only for a short period of time *(386)*.

Three further studies investigated the impact of interventions on general ADL. One randomized trial involving adults above the age of 60 who had had surgery for hip fracture in Finland did not detect any significant effects on general ADL or IADL *(387)*. However, a quasi-experimental study conducted in Thailand found that home modifications improved abilities in all function areas except for participants with severe degrees of difficulties *(388)*, and a cross-sectional study involving participants from Sweden and Germany showed improvements in various aspects of ADL *(389)*.

The certainty of the evidence that people with functional impairments living in accessible environments are better able to accomplish activities of daily living was assessed as **low to moderate**.

7.2.2 Falls/injuries

Studies showed that home modifications aimed at reducing the likelihood of falls and injuries for people with functional impairments were successful in doing so. One randomized trial reported 41% fewer falls after 1 year in the home safety programme with a group of older adults with severe visual impairments, compared with those who did not receive this programme *(341)*. A longitudinal prospective cohort study identified a significant reduction in falls at home and post-fall hospitalizations among frail older adults after the use of a light path coupled with tele-assistance *(390)*. Two other studies reported a significantly lower mortality rate in the intervention group over the control group after the implementation of the multicomponent home modification programme. The programme included training to promote healthy behaviours *(382, 391)*.

The certainty of the evidence that people with functional impairments living in accessible environments have reduced fall and injury rates was assessed as **moderate**.

7.2.3 Mortality

One randomized trial, reported in two papers *(382, 391)* reported a significantly lower mortality rate in the intervention group over the control group up to 2 years after the implementation of the multicomponent programme, which included home modifications as well as training strategies to promote healthy behaviours. However, there was no statistically significant effect on survival 3 years after the intervention.

The certainty of the evidence that living in accessible environments reduces the mortality rate of people with functional impairments was assessed as **low**.

7.2.4 Quality of life

Two randomized trials *(384, 392)* identified the positive effect of interventions on quality of life. Ahmad et al. (2013) found that 2 months after the homes of paraplegic wheelchair users were modified, quality of life was significantly enhanced in the intervention group, compared with the control group *(392)*. Brunnström et al. (2004) found that adjustments to living room lighting increased quality of life and well-being among adults with low vision *(384)*. Conversely, a cross-sectional study with adults with dementia found no association between quality of life and home safety and accessibility factors such as hazards, grab bars and visual cues *(379)*.

The certainty of the evidence that living in accessible environments improves the quality of life of people with functional impairments was assessed as **low**.

7.2.5 Psychological effects

Three studies identified positive psychological effects of home accessibility interventions for people with functional impairments *(382, 393, 394)*. A randomized trial found that older adults with functional difficulties reported significantly less fear of falling following a multicomponent home intervention *(382)*. A quasi-experimental study from Sweden found a significant decrease in fear of falling at 3 months but not at 6 months after the intervention *(394)*. Heywood (2004) reported that 62% of people whose homes had modified for accessibility (through for example installing handrails and grab-rails), reported "feeling safer from accidents" and 77% perceived a positive effect on their health *(393)*.

The certainty of the evidence that people with functional impairments living in accessible environments experience positive psychological effects was assessed as **moderate**.

7.2.6 Participation

One cross-sectional study conducted in Sweden concluded that accessibility problems were significantly associated with less participation and autonomy and more participation problems *(395)*.

7.3 Considerations for implementation of the guideline recommendation

A report from New Zealand concluded that it would be approximately 22 times more cost-efficient to build housing that includes key accessibility features than to retrofit when an unplanned need arises *(396)*. However, in 2006, only 56% of countries had accessibility criteria in their building standards *(397)*. Introducing such national regulations in a large number of countries could therefore lead to more inclusive societies and avoid extensive expenditures on retrofitting. It needs, however, to be noted that globally only a very small proportion of the housing stock will be newly built, while most of the housing stock requires retrofitting. Accessibility needs therefore to be ensured in regulation both for existing and new dwellings. The international standard "ISO 21542:2011 Building construction – Accessibility and usability of the built environment", published by the International Organization for Standardization, specifies a range of requirements and recommendations including on construction aspects of housing accessibility *(398)*. Information on low-cost home modifications to increase housing accessibility in low-income settings is available from community-based rehabilitation programmes in India, using guidelines for care and community integration after spinal cord injury produced by the Government of India and the *WHO Community-based rehabilitation guidelines (399)*.

Besides the public sector, the private sector is a major partner in promoting accessible housing. One such a multistakeholder collaboration has been initiated by the National Cooperative Housing Union in Kenya by linking government, disability groups and the private sector to identify available land and providing technical assistance and loan capital to facilitate accessible housing construction *(400)*. In Australia, the housing industry developed a target of having all new homes meet the Australian *Liveable housing design guidelines* by 2020. Those guidelines describe a number of elements that make a home more responsive to the changing needs of home occupants *(401)*. However, voluntary schemes require extensive education and training programmes to highlight the benefits of accessible housing.

Progress towards increasing the stock of accessible housing should be carefully monitored. If sufficient progress is not being made using a voluntary programme, it may be necessary to introduce a mandatory programme. Such schemes are usually introduced gradually. For example, Portugal's compulsory scheme was phased in over 8 years *(402)*. In Sweden, every local authority is legally obliged to provide home modifications for people with impairments *(380)*. However, planning for home modification requires consultation with service users as well as health and architectural professionals to ensure the users' needs are met appropriately. Home modifications that are poorly implemented due to bad planning or administrative errors may have a negative impact on physical and mental health of persons with impairments *(393)*.

Accessible housing should consider other factors related to healthy housing in addition to usability for occupants. If providing a household with an accessible dwelling entails people moving to another location, it could potentially remove them from social networks, child care support, and work or educational opportunities, affecting health and earning opportunities *(194)*.

7.4 Research recommendations

The research reviewed suggests that living in accessible housing supports the health of people with impairments. However, high-quality research in this area is difficult because allocating people to a comparison group is not always possible: the home modifications might be mandated under law, or it may be unethical to deny or delay accessibility improvements. Table 7.1 lists the research priorities in this area.

Table 7.1 Research recommendations: accessibility

Current state of the evidence	There are relatively few high-quality studies, with most studies to date being observational or small. The participants and types of intervention reviewed vary greatly. Some studies rely on subjective self-reporting rather than objective performance-based measures, and use different psychometric instruments to identify quality of life outcomes. There are few studies conducted outside of high-income settings, and most of the research focuses on the experience of adults. For some studies, it is not clear which component of the intervention was most effective. Future studies might consider using factorial designs to enable analyses of the effects of the specific interventions that make up a multicomponent intervention. Longitudinal studies, using standardized outcome measurements, are required to provide a stronger evidence base for the health and social benefits of home accessibility interventions.
Population of interest	Populations with a range of physical and cognitive impairments. Much of the current evidence is based on research with adults with physical impairments in high-income settings; future research should consider people with cognitive impairments, people in low-income settings, and children and young adults.
Interventions of interest	Improving accessibility of housing. This could include modification of specific furniture and fixtures in the house; structural changes to the inside and immediate outside of the house; and assistive devices that are part of the house. Studies should consider how different accessibility features affect health and social outcomes for people with specific impairments. Research should determine which accessibility features affect these outcomes for people with different impairments.
Comparisons of interest	Groups living in accessible and conventional/unmodified home environments; a group before and after intervention.
Outcomes of interest	Injury rates (especially falls), well-being and quality of life, mental health and depression, dependency on external social or care services, and social participation.
Time stamp	Current systematic review on the association between accessible home environments and the health of people with impairments included studies published up to April 2018.

8

WHO guidelines for other key housing risk factors

8 WHO guidelines for other key housing risk factors

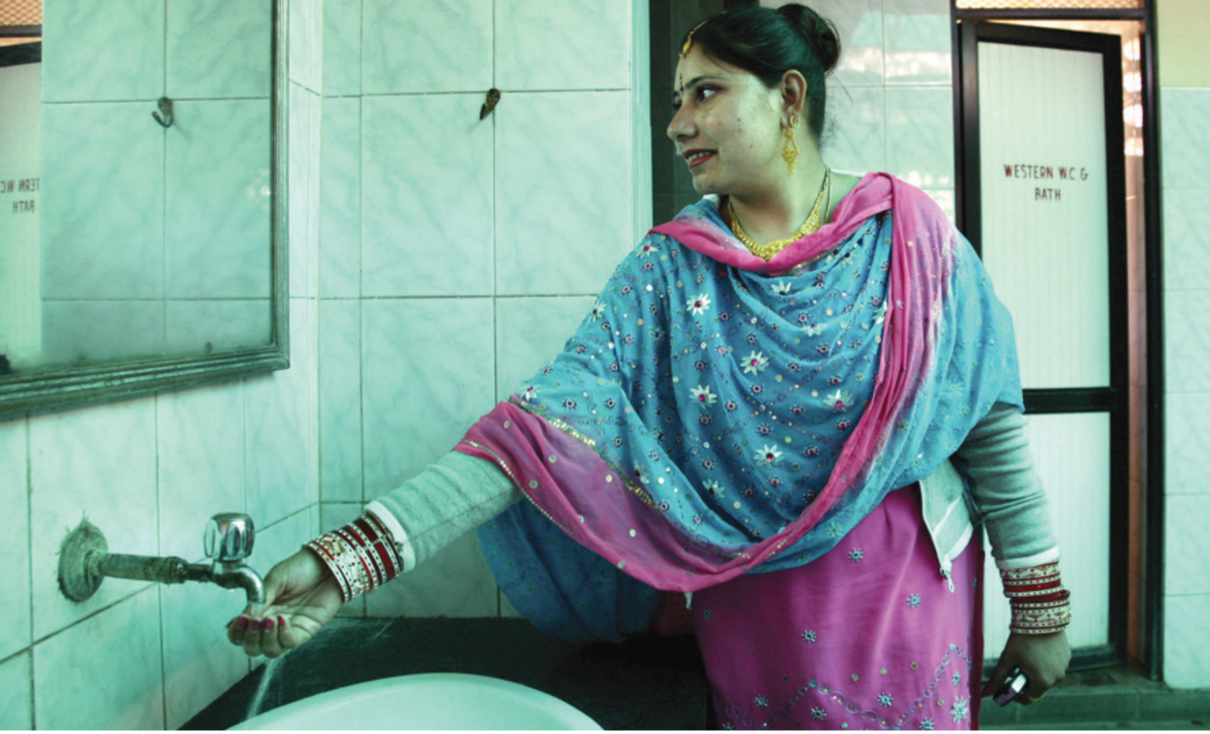
This chapter compiles housing-related guideline recommendations from existing WHO guidelines and guidance documents. While the summarized guideline recommendations are taken verbatim from published WHO guidelines, the introductory paragraphs, which outline the current health burden of each risk factor rely on other sources and have been drafted for the purpose of these guidelines.

8.1 Water

Water is a physiological requirement to sustain adequate hydration, to prepare food, and to maintain hygiene. Contaminated water transmits infectious disease and sometimes non-infectious disease such as lead poisoning from leaded pipes and plumbing. Lack of access to sufficient water discourages hygiene practices. Water can be contaminated by microbes and chemicals at its source, in its storage, and in its transportation, whether by hand-held vessels, tankers or distribution pipes. It is important to ensure that drinking-water supply is reliable, that it is protected from contamination by waste water, and that pipes and storage systems are correctly installed and maintained *(403)*.

Everyone has the right to sufficient, safe, acceptable and physically accessible and affordable water for personal and domestic use, such as for drinking and for hygiene *(404)*. However, in 2015, 844 million people lacked even a basic drinking-water service, including 159 million dependent on surface water. Only eight out of ten people could use improved sources with water available when *(405)*. At least 1.8 billion people use a drinking-water source contaminated with faeces *(406)*. Climate change, increasing water scarcity, population growth, demographic changes and urbanization pose challenges for water supply systems. By 2050, 40% of the world's population will be living in river basins experiencing severe water-stress *(407)*.

Unsafe water and poor sanitation are linked to transmission of diseases such as cholera, diarrhoea illnesses, dysentery, hepatitis A, typhoid and



polio, and lead poisoning from lead drinking-water service lines, or leaded solder, or brass or leaded fixtures. Diarrhoeal disease alone amounts to an estimated 3.6% of the total DALY global burden of disease and is responsible for the deaths of 1.5 million people every year. It is estimated that 58% of that burden, or 842 000 deaths per year, is attributable to inadequate water supply, sanitation and hygiene, mostly in low- and middle-income countries *(132)*. With children particularly at risk from water-related diseases, access to improved sources of water can result in better health and therefore better school attendance *(408)*.

8.1.1 WHO Guidelines for drinking-water quality

Threshold values for water contaminants in drinking-water are available in the WHO *Guidelines for drinking-water quality* (fourth edition published in 2011 and complemented by the first addendum in 2017) *(409, 410)*.[6] WHO documents related to water management in buildings and other aspects of WASH provide more technical guidance on implementation and are listed at the end of this section.

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6 http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/ and http://apps.who.int/iris/bitstream/handle/10665/254637/9789241549950-eng.pdf;jsessionid=E6D91983054C043393978E6A8D216966?sequence=1

Guideline values related to drinking-water contamination

1) **Chemical contaminants:** The selected chemical contaminants displayed in Table 8.1 are associated with potential contamination through pipes and plumbing components and therefore are considered relevant from a building perspective.

Table 8.1 WHO guideline values for drinking-water quality: chemical contaminants I

Compound	Guideline value
Antimony	0.02 mg/l (20 µg/l) As the most common source of antimony in drinking-water appears to be dissolution from metal plumbing and fittings, control of antimony from such sources would be by product control.
Benzo[a]pyrene	0.0007 mg/l (0.7 µg/l) The presence of significant concentrations of benzo[a]pyrene in drinking-water in the absence of very high concentrations of fluoranthene indicates the presence of coal tar particles, which may arise from seriously deteriorating coal tar pipe linings. It is recommended that the use of coal tar based and similar materials for pipe linings and coatings on storage tanks be discontinued.
Copper	2 mg/l (2000 µg/l) In most instances where copper tubing is used as a plumbing material, concentrations of copper will be below the guideline value. However, there are some conditions, such as highly acidic or aggressive waters, that will give rise to much higher copper concentrations, and the use of copper tubing may not be appropriate in such circumstances.
Lead	0.01 mg/l (10 µg/l) This is a provisional guideline value as the key effects of lead seem not to have a threshold. Lead is exceptional compared with other chemical hazards, in that most lead in drinking-water arises from plumbing in buildings, and the remedy consists principally of removing plumbing and fittings containing lead. All other practical measures to reduce total exposure to lead, including corrosion control, should be implemented.
Nickel	0.07 mg/l (70 µg/l) Where nickel leaches from alloys in contact with drinking-water or from chromium- or nickel-plated taps, control is by appropriate control of materials in contact with the drinking-water and flushing taps before using the water.
Vinyl chloride	0.0003 mg/l (0.3 µg/l) As vinyl chloride is a known human carcinogen, exposure to this compound should be avoided as far as practicable, and levels should be kept as low as technically feasible. Vinyl chloride is primarily of concern as a potential contaminant from some grades of polyvinyl chloride pipe and is best controlled by specification of material quality.

The selected chemical contaminants displayed in Table 8.2 are of greatest health concern in some natural waters, and may pose significant health risks in non-piped water supply conditions.

Table 8.2 WHO guideline values for drinking-water quality: chemical contaminants II

Compound	Guideline value
Arsenic	0.01 mg/l (10 µg/l) The guideline value is designated as provisional on the basis of treatment performance and analytical achievability. Arsenic is usually present in natural waters at concentrations of less than 1–2 µg/l. However, in waters, particularly groundwaters, where there are sulfide mineral deposits and sedimentary deposits deriving from volcanic rocks, the concentrations can be significantly elevated. Signs of chronic arsenicism, including dermal lesions, such as hyperpigmentation and hypopigmentation, peripheral neuropathy, skin cancer, bladder and lung cancers and peripheral vascular disease, have been observed in populations ingesting arsenic-contaminated drinking-water. For local non-piped water supplies, the first option for control is often substitution by, or dilution with, microbially safe low-arsenic sources. It may also be appropriate to use alternative sources for drinking and cooking but to use the contaminated sources for purposes such as washing and laundry.
Fluoride	1.5 mg/l (1500 µg/l) Traces of fluorides are present in many waters, with higher concentrations often associated with groundwaters. Skeletal fluorosis (with adverse changes in bone structure) may be observed when drinking-water contains 3–6 mg/l fluoride, particularly with high water consumption. Crippling skeletal fluorosis usually develops only where drinking-water contains over 10 mg/l. The risk of dental fluorosis will depend on the total intake of fluoride from all sources and not just the concentration in drinking-water. A management guidance document on fluoride is available. In some countries, fluoride may also be added to drinking-water in order to provide protection against dental caries, such that final concentrations are usually between 0.5 and 1 mg/l.
Nitrate	50 mg/l (50 000 µg/l) Methaemoglobinaemia has most frequently been associated with private wells. The most appropriate means of controlling nitrate concentrations, particularly in groundwater, is the prevention of contamination. This may take the form of appropriate management of agricultural practices, the careful siting of pit latrines and septic tanks, sewer leakage control, as well as management of fertilizer and manure application and storage of animal manures. It may also take the form of denitrification of wastewater effluents.

2) Bacteria (selected):

Table 8.3 WHO guideline values for drinking-water quality: bacteria

Pathogen	Guideline value
***Legionella* spp.**	There is no guideline value for *Legionella*. Water temperature is an important element of control strategies against Legionella. Wherever possible, water temperatures should be kept outside the range of 25–50 °C and preferably outside the range of 20–50 °C to prevent the growth of the organism. In hot water systems, temperatures leaving heaters should be above 60 °C, and temperatures above 50 °C should be maintained throughout associated pipework. However, maintaining temperatures of hot water above 50 °C may represent a scalding risk in young children, the elderly and other vulnerable groups. Where temperatures in hot or cold water distribution systems cannot be maintained outside the range of 25–50 °C, greater attention to disinfection and strategies aimed at limiting development of biofilms are required.
Escherichia coli	*Escherichia coli* (*E. coli*) or thermotolerant coliform bacteria must not be detectable in any 100 ml sample. The presence of *E. coli* indicates faecal contamination of drinking-water due to cross-contamination. Such cross-contamination may occur in buildings due to cross-connection with non-drinking-water systems or during water transport or storage in non-piped water supply conditions where households need to fetch water at a source outside their home.

Guidelines related to quantity and continuity of drinking-water supply[7]

Access to drinking-water should be optimal. Interventions to increase levels of water service and supply should be prioritized as follows:

Table 8.4 Interventions to increase levels of water service and supply

Service level	Distance/time	Likely volumes of water collected	Public health risk from poor hygiene	Intervention priority and actions
No access	More than 1 km / more than 30-minute round trip	Very low: 5 litres per capita per day	**Very high** Hygiene practice compromised Basic consumption may be compromised	**Very high** Provision of basic level of service Hygiene education Household water treatment and safe storage as interim measure
Basic access	Within 1 km / within 30-minute round trip	Approximately 20 litres per capita per day on average	**High** Hygiene may be compromised Laundry may occur off plot	**High** Provision of improved level of service Hygiene education Household water treatment and safe storage as interim measure
Intermediate access	Water provided on plot through at least one tap (yard level)	Approximately 50 litres per capita per day on average	**Low** Hygiene should not be compromised Laundry likely to occur on plot	**Low** Hygiene promotion still yields health gains Encourage optimal access
Optimal access	Supply of water through multiple taps within the house	100–200 litres per capita per day on average	**Very low** Hygiene should not be compromised Laundry will occur on plot	**Very low** Hygiene promotion still yields health gains

Interruptions to drinking-water supply, either because of intermittent sources or resulting from engineering inefficiencies, are a major determinant of the access to and quality of drinking-water.

[7] These values included in the *WHO Guidelines for drinking-water quality* refer to the WHO publication on *Domestic water quantity, service level and health*. This latter is being updated and new reference values will be ready during 2018.

Guidelines related to water collection and transport

Maintaining the quality of water during collection and manual transport is the responsibility of the household. Good hygiene practices are required and should be supported through hygiene education. Hygiene education programmes should provide households and communities with skills to monitor and manage their water hygiene.

In many low- and middle-income countries, consumers purchase water from kiosks and then carry the water home in a variety of containers of varying size. Measures should be taken to protect vended water from contamination during transport, as well as during storage in the home. These measures include transporting and storing water in containers that are clean, free from both faecal and chemical contamination, and either enclosed, or with narrow openings, and ideally fitted with a dispensing device such as a spigot that prevents hand access and other sources of extraneous contamination. Good hygiene is required and should be supported by educational programmes.

In other cases, particularly in low-income countries, vendors transport and deliver the water to users in tanker trucks. If large volumes are being transported, the addition of chlorine to provide a free residual concentration of at least 0.5 mg/l at the point of delivery to users is desirable. Tankers should also be used solely for water or, if this is not possible, should be thoroughly cleaned prior to use.

Guidelines related to plumbing

Significant adverse health effects have been associated with inadequate plumbing systems within public and private buildings arising from poor design, incorrect installation, alterations and inadequate maintenance.

Numerous factors influence the quality of water within a building's piped distribution system and may result in microbial or chemical contamination of drinking-water. Outbreaks of gastrointestinal disease can occur through faecal contamination of drinking-water within buildings arising from deficiencies in roof storage tanks and cross-connections with wastewater pipes, for example. Poorly designed plumbing systems can cause stagnation of water and provide a suitable environment for the proliferation of *Legionella*. Plumbing materials, pipes, fittings and coatings can result in elevated heavy metal (e.g. lead) concentrations in drinking-water, and inappropriate materials can be conducive to bacterial growth. Potential adverse health effects may not be confined to the individual building. Exposure of other consumers to contaminants is possible through contamination of the local public distribution system, beyond the particular building, through cross-contamination of drinking-water and backflow.

The delivery of water that complies with relevant standards within buildings generally relies on a plumbing system that is not directly managed by the water supplier. Reliance is therefore placed on proper installation of plumbing and, for larger buildings, on building-specific water safety plans (WSPs).

To ensure the safety of drinking-water supplies within the building system, plumbing practices must prevent the introduction of hazards to health. This can be achieved by ensuring that:

- pipes carrying either water or wastes are watertight, durable, of smooth and unobstructed interior and protected against anticipated stresses;
- cross-connections between the drinking-water supply and the wastewater removal systems do not occur;
- roof storage systems are intact and not subject to intrusion of microbial or chemical contaminants;
- hot and cold water systems are designed to minimize the proliferation of *Legionella*;
- appropriate protection is in place to prevent backflow;
- the system design of multistorey buildings minimizes pressure fluctuations;
- waste is discharged without contaminating drinking-water;
- plumbing systems function efficiently.

It is important that plumbers are appropriately qualified, have the competence to undertake necessary servicing of plumbing systems to ensure compliance with local regulations and use only materials approved as safe for use with drinking-water.

Design of the plumbing systems of new buildings should normally be approved prior to construction and be inspected by an appropriate regulatory body during construction and prior to commissioning of the buildings.

For more information on the essential roles of proper drinking-water system and waste system plumbing in public health, see the supporting document *Health aspects of plumbing* (2006) *(411)*.

Guidelines related to dual piped water supply systems

In some locations, households and buildings served with a piped drinking-water supply may also receive piped water from an alternative source for non-potable purposes, creating a dual piped water supply system. The alternative water source is usually provided to reduce the use of high-quality water resources for non-potable uses (e.g. toilets, washing clothes, irrigation) or simply to conserve scarce water resources.

Non-potable piped supplies can potentially introduce health hazards, commonly through accidental cross-connections between potable and non-potable piped supplies. Measures to control health risks from dual piped supply systems include:

- use of good design practices that prevent cross-connections;
- unambiguous labelling of both systems to ensure that the non-potable supply is not mistaken for the potable supply;
- installation of the non-potable piped system only by qualified plumbers;
- regulation of non-potable piped systems by the authority responsible for drinking-water surveillance;
- public communication about the potential health risks from exposure to non-potable water through cross-connections and the dangers of modifying systems by inexperienced and non-certified individuals.

Increasingly in high-income countries, dual systems are being installed at a household level or in public buildings. Guidance should be provided on installation, particularly where this is by non-certified individuals. Potable water supplied into the building should be fitted with a non-return valve in order to prevent backflow into the public water supply.

Guidelines related to water storage and handling in the house

Safe water storage and handling in households is important for ensuring that treated water does not become re-contaminated. Studies have shown that safe storage alone can significantly reduce diarrhoeal disease *(412, 413)* which highlights the importance and the cost–effectiveness of this measure. Increasingly a number of household water treatment products incorporate safe storage into their design (as is often the case for filters) or through the presence of a chlorine residual *(414)*.

With climate change and increasing fluctuations in water supply and the resulting need to store water in the household, safe storage is likely to become even more important in the future. Furthermore, safe storage is also associated with other health benefits beyond diarrhoeal disease reduction, such as decreasing the risk of dengue by reducing breeding grounds for the mosquito vector.

Improved containers protect stored household water from the introduction of microbial contaminants via contact with hands, dippers, other faecally contaminated vehicles or the intrusion of vectors. The use of storage containers with narrow openings for filling, and dispensing devices such as spouts or taps/spigots is recommended *(415)*.

The installation of large capacity storage tanks in households is increasingly common, particularly where water supply is intermittent. Tanks previously used for holding non-food-grade liquids such as fuel and sewage should not be used. Water storage tanks should be cleaned and disinfected regularly. Tanks must be easy to clean, and have no sharp corners that may hold dirt. In addition, tanks must be covered and fitted with an access point with a lockable lid *(416)*.

Guidelines related to water treatment in the home and water safety plans

A WSP is a comprehensive risk assessment and risk management approach that includes all steps in the water supply from catchment to consumer. The primary objectives of a WSP in ensuring good drinking-water supply practice are the prevention or minimization of contamination of source waters, the reduction or removal of contamination through treatment processes and the prevention of contamination during central storage, distribution and household handling and storage of drinking-water. At a minimum, a WSP comprises three key components: an assessment of the drinking-water supply system up to the point of consumption in households to determine whether the system can deliver water that meets identified targets; identification and operational monitoring of measures to control identified risks; and management and communication plans describing actions to be taken during normal operations or incident conditions *(414)*.

Household water treatment (HWT) and safe storage is one particular option within a broader WSP to make water safer to drink *(414)*. HWT approaches have the potential to have rapid and significant positive health impacts in situations where piped water systems are not possible and where people rely on source water that may be contaminated or where stored water becomes contaminated because of unhygienic handling during transport or in the home. HWT is not a substitute for sustainable access to safe drinking-water, but is an important interim measure for removing pathogens from drinking-water and reducing disease risk *(414)*.

There are a number of different HWT methods and technologies that aim to reduce microbial pathogens, including disinfection by chemicals, heat, ultraviolet radiation, filtration, or combinations of these approaches. These treatment methods and the related technologies vary in their ability to remove the main classes of enteric pathogens that pose health risks (bacteria, protozoa and viruses). In order to comprehensively assess effectiveness, WHO has set tiered health-based $\log_{10}$ reduction performance targets for household water treatment products for the removal of bacteria, viruses and protozoa *(414)*. These performance targets are based on microbial risk models using assumed levels of reference pathogens in untreated water. The performance recommendations and related targets are available in the report *Evaluating household water treatment options: health-based targets and microbiological performance specifications (417)*. The targets allow for the classification of HWT products into three descending levels of performance: 3-star, 2-star and 1-star. Performance that does not meet the minimum level is given no stars. The performance targets are shown in Table 8.5 *(414)*.

Table 8.5 Performance targets for household water treatment products for the removal of bacteria, viruses and protozoa

Performance classification	Required minimum $\log_{10}$ reduction			Interpretation (with correct and consistent use)
	Bacteria	Viruses	Protozoa	
★★★	≥4	≥5	≥4	Comprehensive protection (very high pathogen removal)
★★	≥2	≥3	≥2	Comprehensive protection (high pathogen removal)
★	Meets at least 2-star criteria for two classes of pathogens			Targeted protection
—	Fails to meet WHO performance criteria			Little or no protection

Since 2014 WHO has been evaluating products against these performance targets through the WHO International Scheme to Evaluate Household Water Treatment Technologies ("the Scheme"). The objective of the Scheme is to independently and consistently evaluate the microbiological performance of household water treatment technologies, and in so doing, guide Member States and procuring United Nations agencies in the selection of these technologies *(418)*.

Selected WHO recommendations, guidance and tools related to buildings and drinking-water

There are a range of WHO documents for different stakeholders in the area of buildings and water-related health prevention. These documents provide technical guidance in relation to water supply and treatment as well as water-related infrastructure and plumbing within buildings.

Results of round I of the WHO International Scheme to Evaluate Household Water Treatment Technologies (2016):
http://apps.who.int/iris/bitstream/10665/204284/1/9789241509947_eng.pdf?ua=1

Technical notes on drinking-water, sanitation and hygiene in emergencies (2013):
http://www.who.int/water_sanitation_health/publications/2011/WHO_TN_03_Cleaning_and_disinfecting_water_storage_tanks_and_tankers.pdf)

Evaluating household water treatment options:
health-based targets and microbiological performance specifications (2011): http://www.who.int/water_sanitation_health/publications/2011/household_water/en/

Water safety in buildings (2011):
http://whqlibdoc.who.int/publications/2011/9789241548106_eng.pdf?ua=1

WHO Guidelines for drinking-water quality (2011):
http://apps.who.int/iris/bitstream/10665/44584/1/9789241548151_eng.pdf

Legionella and the prevention of legionellosis (2007):
http://www.who.int/water_sanitation_health/emerging/legionella.pdf

Health aspects of plumbing (2006):
http://www.who.int/water_sanitation_health/publications/plumbinghealthasp.pdf

Managing water in the home: accelerated health gains from improved water supply (2002):
http://www.who.int/water_sanitation_health/dwq/WSH02.07.pdf

8.2 Air quality

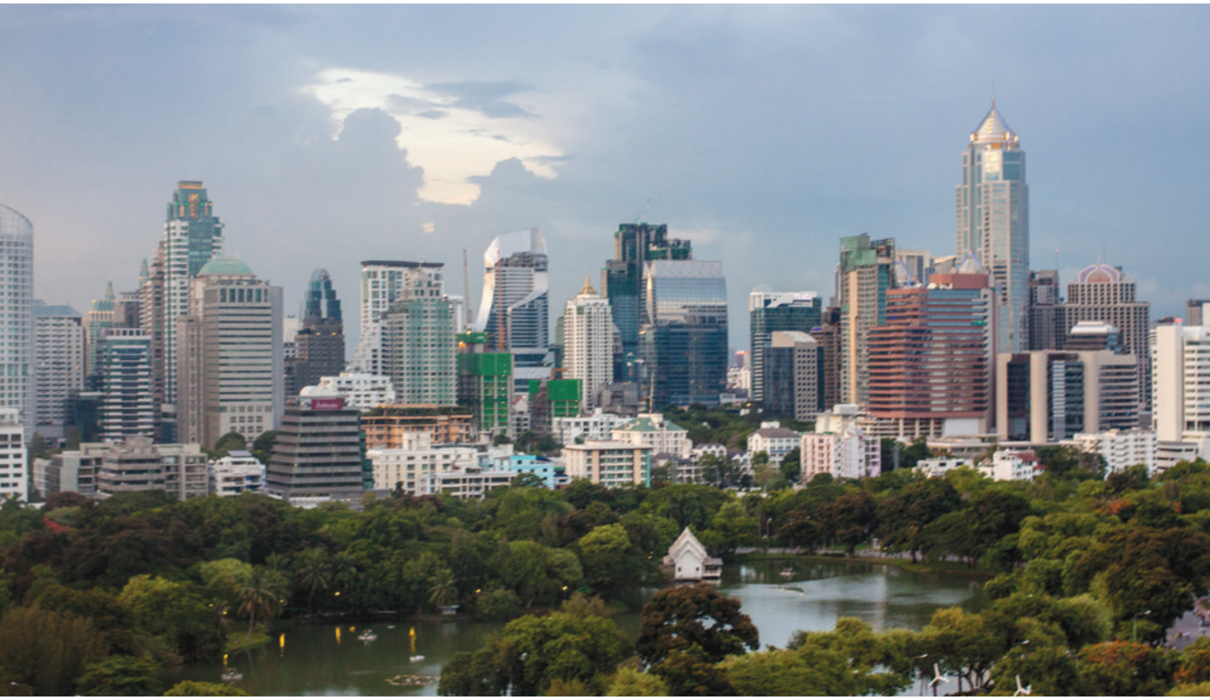
This section focuses on WHO air quality recommendations of particular relevance to the housing and health context. These include specific indoor air quality recommendations, as well as recommendations for ambient air quality as pollutants may affect housing conditions through ventilation and infiltration, and because some guidelines for ambient air quality are also valid for indoor conditions.

Indoor air quality is affected by a number of aspects of the indoor and outdoor environment, including the ventilation system, structure of the dwelling, its situation, the cooking, lighting and heating devices used, the types of furnishing, adhesives and coatings, and outdoor pollution and tobacco smoking by occupants or infiltrations of tobacco smoke coming from neighbouring units. Damp or humid indoor air encourages mould growth and may indicate that there is insufficient ventilation to disperse moisture generated from indoor activities like cooking and bathing. Poor quality heating and cooking devices, and a lack of ventilation, can result in polluted indoor air. Around 3 billion people cook using polluting open fires or simple stoves fuelled by kerosene, biomass (wood, animal dung and crop waste) and coal; most of them living in low- and middle-income countries *(419)*. Household air quality can also be affected by the presence of the carcinogen radon, a naturally occurring radioactive gas that can accumulate in enclosed spaces, including homes. Poor air quality can result from the presence of furnishings and building materials containing toxins such as formaldehyde *(420–422)*. Tobacco smoke is an important indoor air pollutant, which contains carcinogens and other toxic components (see section 8.3). Finally, natural sources of outdoor air pollution, for example stemming from dust storms, or industry and transport related pollutants, can enter the home and degrade the air *(12, 245)*.

Poor indoor air quality has a number of adverse health effects. It is associated with allergies, a weakened immune system, cancer, and skin, eye, nose and throat irritation. It can adversely affect the reproductive, nervous and cardiovascular systems. Each year, approximately 3.8 million people die prematurely from illness attributable to the household air pollution caused by the inefficient use of solid fuels and kerosene for cooking *(419)*. Further, ambient air pollution in both cities and rural areas was estimated to cause 4.2 million premature deaths worldwide in 2016 *(423)*. There is a strong association between indoor dampness and mould and a wide range of respiratory symptoms. In Europe, it is estimated that, annually, 0.07 asthma-related deaths and 50 asthma-related DALYs per 100 000 children are associated with exposure to dampness in dwellings *(18)*.

Expelling or minimizing pollutants, such as through replacing polluting stoves and lamps with healthier alternatives, plays a role in ensuring acceptable indoor air quality *(424)*. Ventilation is also a crucial intervention. Ventilation standards for housing are available from several organizations, such as the ASHRAE Standard 62 *(243)* and in the Buildings Performance Institute Europe *(244)*.

Other relevant guidance is provided by three recent *WHO Guidelines for indoor air* quality publications: *Dampness and mould* (2009), *Selected pollutants* (2010) and *Household fuel combustion* (2014). Guidance on exposure to some other contaminants that are sometimes present in the indoor environment, and that are not covered by those guidelines, is provided by the *WHO Air quality guidelines for Europe* (2000; updated 2006 for specific pollutants) and the *WHO Handbook on indoor* radon (2009).



8.2.1 WHO Guidelines for indoor air quality

WHO Guidelines for indoor air quality: selected pollutants (2010)[8]

Table 8.6 WHO guideline values for indoor air quality: selected pollutants

Compound	Guideline value
Benzene	• No safe level of exposure can be recommended • Unit risk of leukaemia per 1 µg/m³ air concentration is 6×10^{-6} • The concentrations of airborne benzene associated with an excess lifetime risk of 1/10 000, 1/100 000 and 1/1 000 000 are 17, 1.7 and 0.17 µg/m³, respectively
Carbon monoxide	• 15 minutes – 100 mg/m³ • 1 hour – 35 mg/m³ • 8 hours – 10 mg/m³ • 24 hours – 7 mg/m³
Formaldehyde	• 0.1 mg/m³ – 30-minute average
Naphthalene	• 0.01 mg/m³ – annual average
Nitrogen dioxide	• 200 µg/m³ – 1-hour average • 40 µg/m³ – annual average
Polycyclic aromatic hydrocarbons	• No threshold can be determined and all indoor exposures are considered relevant to health • Unit risk for lung cancer for polycyclic aromatic hydrocarbon mixtures is estimated to be 8.7×10^{-5} per ng/m³ of benzo[a]pyrene (B[a]P) • The corresponding concentrations for lifetime exposure to B[a]P producing excess lifetime cancer risks of 1/10 000, 1/100 000 and 1/1 000 000 are approximately 1.2, 0.12 and 0.012 ng/m³, respectively
Radon	• The excess lifetime risk of death from radon-induced lung cancer (by the age of 75 years) is estimated to be 0.6×10^{-5} per Bq/m³ for lifelong non-smokers and 15×10^{-5} per Bq/m³ for current smokers (15–24 cigarettes per day); among ex-smokers, the risk is intermediate, depending on time since smoking cessation • The radon concentrations associated with an excess lifetime risk of 1/100 and 1/1000 are 67 and 6.7 Bq/m³ for current smokers and 1670 and 167 Bq/m³ for lifelong non-smokers, respectively
Trichloroethylene	• Unit risk estimate of 4.3×10^{-7} per µg/m³ • The concentrations of airborne trichloroethylene associated with an excess lifetime cancer risk of 1:10 000, 1:100 000 and 1:1 000 000 are 230, 23 and 2.3 µg/m³, respectively
Tetrachloroethylene	• 0.25 mg/ m³ – annual average

[8] Source: http://www.euro.who.int/__data/assets/pdf_file/0009/128169/e94535.pdf

WHO Guidelines for indoor air quality: dampness and mould (2009)[9]

Dampness in buildings is affected by indoor and outdoor conditions in relation to air temperature and air humidity, the degree of air exchange between indoor and outdoor settings, and the generation of humidity within a given building. It furthermore depends on construction type, building materials and quality of a building whether a certain level of humidity is considered a risk factor for dampness or not.

Mould growth is affected by various building parameters such as moisture, temperature, ventilation and building materials, as well as the behaviour of a building's occupants. However, mould growth always signals inadequate building features and a potential health risk to be remediated, and there is no exposure value for mould growth that can be considered safe for health. The same applies to mould spores which are practically omnipresent in residential indoor environments.

Therefore, WHO recommendations on mould and dampness were developed as qualitative guidance instead of quantitative exposure limits related to dampness, mould growth, species or occurrence of spores.

Guideline recommendations

- Persistent dampness and microbial growth on interior surfaces and in building structures should be avoided or minimized, as they may lead to adverse health effects.
- Indicators of dampness and microbial growth include the presence of condensation on surfaces or in structures, visible mould, perceived mouldy odour and a history of water damage, leakage or penetration. Thorough inspection and, if necessary, appropriate measurements can be used to confirm indoor moisture and microbial growth.
- As the relationships between dampness, microbial exposure and health effects cannot be quantified precisely, no quantitative health-based guideline values or thresholds can be recommended for acceptable levels of contamination with micro-organisms. Instead, it is recommended that dampness and mould-related problems be prevented. When they occur, they should be remediated because they increase the risk of hazardous exposure to microbes and chemicals.

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9 Source: http://www.euro.who.int/__data/assets/pdf_file/0017/43325/E92645.pdf?ua=1

- Well-designed, well-constructed, well-maintained building envelopes are critical to the prevention and control of excess moisture and microbial growth, as they prevent thermal bridges and the entry of liquid or vapour-phase water. Management of moisture requires proper control of temperatures and ventilation to avoid excess humidity, condensation on surfaces and excess moisture in materials. Ventilation should be distributed effectively throughout spaces, and stagnant air zones should be avoided.
- Building owners are responsible for providing a healthy workplace or living environment free of excess moisture and mould, by ensuring proper building construction and maintenance. The occupants are responsible for managing the use of water, heating, ventilation and appliances in a manner that does not lead to dampness and mould growth.
- Local recommendations for different climatic regions should be updated to control dampness-mediated microbial growth in buildings and to ensure desirable indoor air quality.
- Dampness and mould may be particularly prevalent in poorly maintained housing for low-income people. Remediation of the conditions that lead to adverse exposure should be given priority to prevent an additional contribution to poor health in populations who are already living with an increased burden of disease.

WHO Guidelines for indoor air quality: household fuel combustion (2014)[10]
The recommendations on household fuel combustion include four specific recommendations, and a best-practice recommendation addressing linked health and climate impacts.

Guideline recommendation on emission rate targets (strong recommendation)
Emission rates from household fuel combustion should not exceed the following emission rate targets (ERTs) for particles with aerodynamic diameters of less than 2.5 μm (PM2.5) and carbon monoxide (CO), based on the values for kitchen volume, air exchange and duration of device use per day set out in Tables 8.7–8.9 and which are assumed to be representative of conditions in low- and middle-income countries. This recommendation focuses on the two most important products of incomplete combustion, PM2.5

[10] Source: http://apps.who.int/iris/bitstream/10665/141496/1/9789241548885_eng.pdf?ua=1

and CO. However, WHO recognizes the importance of other pollutants as well, for example, toxic components of coal or emissions of nitrogen dioxide from gas appliances.

Table 8.7 Input distributions for air exchange rates, kitchen volumes and device burn times used in the development of emission rate targets

Parameter	Unit	Geometric mean	Range		Standard deviation
			Minimum	Maximum	
Air exchange rate (a)	Per hour	15	5	45	7.5
Kitchen volume (V)	m^3	30	5	100	15
Device burn time	Hours per day	4	0.75	8	2

For the vented devices listed in Tables 8.8 and 8.9, an average of 25% (range 1–50%, standard deviation = 10%) of total emissions is assumed to enter the room.

Table 8.8 Emission rate targets for meeting WHO air quality guidelines for PM2.5, including a less stringent intermediate ERT for which 60% homes would meet the guideline

Emission rate targets	Emission rate (mg/min)	Percentage of kitchens meeting AQG (10 µg/m³)	Percentage of kitchens meeting AQG IT-1 (35 µg/m³)[11]
Unvented			
Intermediate ERT	1.75	6	60
ERT	0.23	90	100
Unvented			
Intermediate ERT	7.15	9	60
ERT	0.80	90	100

Table 8.9 Emission rate targets for meeting WHO air quality guidelines for CO, including a less stringent intermediate ERT for which 60% homes would meet the guideline

Emission rate targets	Emission rate (mg/min)	Percentage of kitchens meeting AQG (7 mg/m³)
Unvented		
Intermediate ERT	0.35	60
ERT	0.16	90
Unvented		
Intermediate ERT	1.45	60
ERT	0.59	90

[11] AQG IT-1 represents the interim target for the air quality guidelines (AQG) if the recommended guideline value cannot be achieved.

Guideline recommendations on policies during transition to technologies and fuels that meet WHO air quality guidelines (strong recommendation)
Governments and their implementing partners should develop strategies to accelerate efforts to meet the above air quality guidelines' emission ERTs. Where intermediate steps are necessary, transition fuels and technologies that offer substantial health benefits should be prioritized.

Guideline recommendation on household use of coal (strong recommendation)
Unprocessed coal should not be used as a household fuel. In this context, unprocessed coal is defined as coal that has not been treated by chemical, physical, or thermal means to reduce contaminants.

Guideline recommendation on household use of kerosene (paraffin) (conditional recommendation)
The household use of kerosene is discouraged while further research into its health impacts is conducted. Existing evidence shows that household use of kerosene can lead to levels of PM and other pollutants that exceed WHO guidelines. As well, the risk of burns, fires and poisoning, associated with the use of kerosene in developing countries is a cause for concern.

Good practice recommendation on securing health and climate co-benefits
Considering the opportunities for synergy between climate policies and health, including financing, WHO recommends that governments and other agencies developing and implementing policy on climate change mitigation consider action on household energy and carry out relevant assessments to maximize health and climate gains.

8.2.2 WHO Guidelines for ambient air quality

WHO Air quality guidelines – global update 2005 (2006)[12]
The guideline values presented in Table 8.10 relate to compounds also found in the indoor environment. Guideline values from this document relating to other contaminants relevant to housing (PM2.5, PM10) have been supported by the *WHO Guidelines for indoor air quality: selected pollutants* (2010), as already summarized above. These guidelines also provide a more recent indoor air-specific value for nitrogen dioxide.

[12] Source: http://www.who.int/phe/health_topics/outdoorair/outdoorair_aqg/en/

Table 8.10 Guideline values from WHO Air quality guidelines – global update 2005

Compound	Guideline value valid indoors and outdoors	Interim target levels[13]		
		IT-1	IT-2	IT-3
PM2.5	10 µg/m³ annual mean 25 µg/m³ 24-hour mean	35 µg/m³ 75 µg/m³	25 µg/m³ 50 µg/m³	15 µg/m³ 37.5 µg/m³
PM10	20 µg/m³ annual mean 50 µg/m³ 24-hour mean	70 µg/m³ 150 µg/m³	50 µg/m³ 100 µg/m³	30 µg/m³ 75 µg/m³
Ozone	100 µg/m³ daily maximum 8-hour mean	160 µg/m³	—	—
Sulfur dioxide	20 µg/m³ 24-hour mean 500 µg/m³ 10-minute mean	125 µg/m³ —	50 µg/m³ —	— —

For many other air pollutants, the second edition of the *WHO Air quality guidelines for Europe* (2000)[14] provides global WHO recommendations on air pollution exposure. In the absence of updated or indoor-specific guideline values, the air quality guidelines are considered applicable for indoor exposure as well. An update of these guidelines is under way.

8.3 Tobacco smoke

Involuntary (or passive) smoking is the exposure to SHS, which is a mixture of exhaled mainstream smoke and side stream smoke released from a smouldering cigarette or other smoking device (cigar, pipe, bidi, hookah etc.) and diluted with ambient air. Second-hand tobacco smoke is also referred to as "environmental" tobacco smoke. Involuntary smoking involves inhaling carcinogens and other toxic components that are present in SHS *(425)*.

Second-hand smoke is estimated to have caused about 603 000 premature deaths in 2004. These include 166 000 deaths from lower respiratory infections and 1 100 from asthma in children, and 35 800 deaths from asthma, 21 000 deaths from lung cancer and 379 000 deaths from IHD in adults. This disease burden amounts in total to about 10.9 million DALYs. Of all deaths attributable to SHS, 28% occur in children, and 47% in women *(426)*.

Second-hand tobacco smoke is a serious health challenge in indoor settings where the exposure can quickly accumulate.

[13] Three interim targets (IT) were defined, which have been shown to be achievable with successive and sustained abatement measures. Countries may find these IT helpful in gauging progress over time in the difficult process of steadily reducing population exposures to PM.

[14] http://www.euro.who.int/__data/assets/pdf_file/0005/74732/E71922.pdf?ua=1

8.3.1 WHO Guidelines for indoor air quality: selected pollutants (2010)[15]

The WHO guidelines for environmental tobacco smoke published in the second edition of the *WHO Air quality guidelines for Europe*, stating that there is no evidence for a safe exposure level, are clear and remain valid.

8.3.2 Protection from exposure to second-hand tobacco smoke: policy recommendations (2007)[16]

Scientific evidence has firmly established that there is no safe level of exposure to SHS, a pollutant that causes serious illnesses in adults and children. There is also indisputable evidence that implementing 100% smoke-free environments is the only effective way to protect the population from the harmful effects of exposure to SHS.

8.4 Noise

Noise levels in the home result from noise inside and outside. Inside the dwelling, ventilation systems, machines and home appliances contribute to noise levels. Outside the dwelling, sources of noise include: road, rail and air traffic; construction and public works; sporting events; playgrounds, schools and public spaces; animals; bars and restaurants; and neighbouring dwellings. The expansion of urban activities, highway systems, airports, roads and low-quality building construction patterns increase the level of noise that people are exposed to in the home *(427)*.

Exposure to noise can lead to auditory and non-auditory effects on health. Through direct injury to the auditory system, noise leads to auditory effects such as hearing loss and tinnitus. As well, noise is a non-specific stressor that has been shown to adversely affect human health, especially following long-term exposure. This is due to psychological and physiological distress as well as disturbance of the organism's homeostasis and increasing allostatic load *(428)*. The main recognized effects from environmental noise include annoyance, cardiovascular disease, cognitive impairment and effects on sleep, affecting in particular vulnerable population groups as pregnant women, etc.

[15] Source: http://www.euro.who.int/__data/assets/pdf_file/0009/128169/e94535.pdf

[16] Source: http://apps.who.int/iris/bitstream/10665/43677/1/9789241563413_eng.pdf

The burden of disease due to environmental noise has been estimated for western Europe. With conservative assumptions applied to the calculation methods, it is estimated that DALYs lost from environmental noise equate to 61 000 years for IHD, 45 000 years for cognitive impairment of children, 903 000 years for sleep disturbance, 22 000 years for tinnitus and 654 000 years for annoyance. These results indicate that at least 1 million healthy life years are lost every year from traffic-related noise in western Europe. Sleep disturbance and annoyance, mostly related to road traffic noise, comprise the main health-related burden of environmental noise *(427)*.

8.4.1 WHO Guidelines for noise

Guideline recommendations for the WHO European Region have been established regarding night noise (2009) and, recently, for environmental noise (2018).

WHO Night noise guidelines for Europe (2009)[17]

The *WHO Night noise guidelines for Europe* are specific recommendations for noise exposure levels at night, issued by the WHO Regional Office for Europe in 2009. The guidelines provide evidence-based advice to Member States for the development of future legislation and policy action in the area of assessment and control of night noise exposure. The guideline values are:

Night noise guideline value:	40dB $L_{\text{night, outside}}$[18]
Interim target value:	55dB $L_{\text{night, outside}}$

To protect the public, including the most vulnerable groups, such as children, chronically ill and elderly people, from the adverse health effects of night noise, an $L_{\text{night value}}$ of 40 dB was recommended as the target for all sources of noise. Further, an $L_{\text{night value}}$ of 55 dB was recommended as an IT for countries that could not follow the guidelines in the short term for various reasons or where policy-makers chose to adopt a stepwise approach.

17 Source: http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf

18 L_{night}, outside is the night-time noise indicator (L_{night}) of Directive 2002/49/EC of 25 June 2002: the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year, in which the night is eight hours (usually 23.00–07.00 local time), a year is a relevant year as regards the emission of sound and an average year as regards the meteorological circumstances, the incident sound is considered, the assessment point is the same as for L_{den}. See Official Journal of the European Communities, 18.7.2002, for more details.

WHO Environmental noise guidelines for the European Region (2018)[19]

The *WHO Environmental noise guidelines for the European Region* provide recommendations for protecting human health from exposure to environmental noise originating from various sources such as transportation (road traffic, railway and aircraft) noise, wind turbine noise and leisure noise.

Table 8.11 **Recommendations of the WHO Environmental noise guidelines for the European Region**

Source of noise	Recommendation	Strength of recommendation
Road traffic noise	For average noise exposure, the GDG strongly recommends reducing noise levels produced by road traffic to below 53 dB L_{den}, as road traffic noise above this level is associated with adverse health effects.	Strong
	For night noise exposure, the GDG strongly recommends reducing noise levels produced by road traffic during night time to below 45 dB L_{night}, as night-time road traffic noise above this level is associated with adverse effects on sleep.	Strong
	To reduce health effects, the GDG strongly recommends that policy-makers implement suitable measures to reduce noise exposure from road traffic in the population exposed to levels above the guideline values for average and night noise exposure. For specific interventions, the GDG recommends reducing noise both at the source and on the route between the source and the affected population by changes in infrastructure.	Strong
Railway noise	For average noise exposure, the GDG strongly recommends reducing noise levels produced by railway traffic to below 54 dB L_{den}, as railway noise above this level is associated with adverse health effects.	Strong
	For night noise exposure, the GDG strongly recommends reducing noise levels produced by railway traffic during night time to below 44 dB L_{night}, as night-time railway noise above this level is associated with adverse effects on sleep.	Strong
	To reduce health effects, the GDG strongly recommends that policy-makers implement suitable measures to reduce noise exposure from railways in the population exposed to levels above the guideline values for average and night noise exposure. There is, however, insufficient evidence to recommend one type of intervention over another.	Strong

[19] Source: www.euro.who.int/en/env-noise-guidelines

Table 8.11 Recommendations of the WHO Environmental noise guidelines for the European Region, continued

Source of noise	Recommendation	Strength of recommendation
Aircraft noise	For average noise exposure, the GDG strongly recommends reducing noise levels produced by aircraft to below 45 dB L_{den}, as aircraft noise above this level is associated with adverse health effects.	Strong
	For night noise exposure, the GDG strongly recommends reducing noise levels produced by aircraft during night time to below 40 dB L_{night}, as night-time aircraft noise above this level is associated with adverse effects on sleep.	Strong
	To reduce health effects, the GDG strongly recommends that policy-makers implement suitable measures to reduce noise exposure from aircraft in the population exposed to levels above the guideline values for average and night noise exposure. For specific interventions, the GDG recommends implementing suitable changes in infrastructure.	Strong
Wind turbine noise	For average noise exposure, the GDG conditionally recommends reducing noise levels produced by wind turbines to below 45 dB L_{den}, as wind turbine noise above this level is associated with adverse health effects.	Conditional
	No recommendation is made for average night noise exposure L_{night} of wind turbines. The quality of evidence of night-time exposure to wind turbine noise is too low to allow a recommendation.	N/A
	To reduce health effects, the GDG conditionally recommends that policy-makers implement suitable measures to reduce noise exposure from wind turbines in the population exposed to levels above the guideline values for average noise exposure. No evidence is available, however, to facilitate the recommendation of one particular type of intervention over another.	Conditional
Leisure noise	For average noise exposure, the GDG conditionally recommends reducing the yearly average from all leisure noise sources combined to 70 dB $L_{Aeq,24h}$ as leisure noise above this level is associated with adverse health effects. The equal energy principle can be used to derive exposure limits for other time averages, which might be more practical in regulatory processes.	Conditional
	For single-event and impulse noise exposures, the GDG conditionally recommends following existing guidelines and legal regulations to limit the risk of increases in hearing impairment from leisure noise in both children and adults.	Conditional
	Following a precautionary approach, to reduce possible health effects, the GDG strongly recommends that policy-makers take action to prevent exposure above the guideline values for average noise and single-event and impulse noise exposures. This is particularly relevant as a large number of people may be exposed to and at risk of hearing impairment through the use of personal listening devices. There is insufficient evidence, however, to recommend one type of intervention over another.	Strong

8.5 Asbestos

Asbestos refers to a group of minerals currently or historically used for many products. The range of applications for asbestos includes in building construction, cement, thermal and electric insulation, fire blankets and industrial fire curtains, gaskets and friction materials (e.g. vehicle brake shoes and brake pads and clutches). Asbestos is found in houses in floor tiling, textured ceilings, roof shingles, thermal insulation, electric insulation (around boilers, ducts, pipes, sheeting and fireplaces), pipe cement, glue and joint compound. Asbestos is used as a loose fibrous mixture, and can be inhaled and ingested *(429)*.

Exposure to asbestos fibres occurs particularly in circumstances where asbestos products have become degraded, such as when housing is in poor repair, or during building maintenance, renovation, demolition and destruction (such as might happen in a disaster). In addition, workers are exposed to asbestos in asbestos mining and milling, when asbestos is used as part of the production process, or when installing or disposing of materials that contain asbestos. Such workers can bring fibres into the home on their clothing *(429)*.

Occupational and domestic exposure to asbestos is associated with a number of cancers, including lung cancer, larynx cancer, mesothelioma, cancer of the ovaries and stomach cancer *(430–432)*. There is no safe level for asbestos exposure *(432)*.

The global burden of disease attributable to asbestos was estimated to amount to 107 000 deaths and 1 523 000 DALYs in 2004. Among these, 41 000 deaths and 370 000 DALYs were due to asbestos-caused lung cancer, and 7000 deaths and 380 000 DALYs were due to asbestosis. The remaining 59 000 deaths and 773 000 DALYs were attributed to malignant mesothelioma *(316)*. About one in every three deaths from occupational cancer is caused by asbestos. Currently, about 125 million people in the world are exposed to asbestos in the workplace *(433)*. In addition, it is estimated that several thousand deaths annually can be attributed to exposure to asbestos in the home *(434)*.

8.5.1 WHO Guidelines and recommendations for the use of asbestos

Various WHO documents provide guidance and recommendations related to the use of asbestos and the prevention of asbestos-related diseases. The following section summarizes the most relevant recommendations and guidelines.

WHO Air quality guidelines for Europe (second edition) (2000)[20,21]
Air quality guideline value for asbestos
Asbestos is a proven human carcinogen (IARC Group 1). No safe level can be proposed for asbestos because a threshold is not known to exist. Exposure should therefore be kept as low as possible.

WHO Guidelines for drinking-water quality (fourth edition) (2011)[22]
Drinking-water quality guideline value for asbestos
There is no guideline value for asbestos in drinking-water. There is no consistent evidence that ingested asbestos is hazardous to health. Therefore, no health-based guideline value for asbestos in drinking-water has been established. The primary issue surrounding asbestos-cement pipes is for people working on the outside of the pipes (e.g. cutting pipe), because of the risk of inhalation of asbestos dust.

WHO report Chrysotile asbestos (2014)[23]
Recommendations on the elimination of asbestos-related diseases
Bearing in mind that there is no evidence for a threshold for the carcinogenic effect of asbestos, including chrysotile, and that increased cancer risks have been observed in populations exposed to very low levels, the most efficient way to eliminate asbestos-related diseases is to stop using all types of asbestos.

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20 Source: http://www.euro.who.int/__data/assets/pdf_file/0005/74732/E71922.pdf?ua=1

21 The *WHO Air quality guidelines for Europe* also provided guidelines on man-made vitreous fibres (such as rock wool, glass wool or ceramic fibres) which often are used as insulation material. Rock wool, slag wool, glass wool and ceramic fibres have been categorized as possibly carcinogenic to humans while glass filaments were not considered classifiable as to their carcinogenicity to humans.

22 Source: http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/

23 Source: http://apps.who.int/iris/bitstream/10665/143649/1/9789241564816_eng.pdf?ua=1

Continued use of asbestos cement in the construction industry is a particular concern, because the workforce is large, it is difficult to control exposure, and in-place materials have the potential to deteriorate and pose a risk to those carrying out alterations, maintenance and demolition. In its various applications, asbestos can be replaced by some other fibre materials and by other products that pose less or no risk to health.

Materials containing asbestos should be encapsulated, and, in general, it is not recommended to carry out work that is likely to disturb asbestos fibres. If necessary, such work should be carried out only under strict control measures to avoid exposure to asbestos, such as encapsulation, wet processes, local exhaust ventilation with filtration, and regular cleaning. It also requires the use of personal protective equipment – special respirators, safety goggles, protective gloves and clothing – and the provision of special facilities for their decontamination.

8.6 Lead

Lead is a highly toxic metal, which is or has been used in many products in common usage, including petrol, batteries, paints, electronics, jewellery, ceramics, glass, water pipes and other plumbing fittings. People are exposed to lead at work or in their local environment, where lead is mined, recycled, burned or used in industry. In addition, people can be exposed to lead in the home *(435)*. As lead-based paint deteriorates, it flakes and contaminates dust in and around the home and soil *(436)*. Food kept in containers that have leaded glaze or lead solder can become contaminated. Water is contaminated through lead pipes, solder and fittings. Finally, people who work with lead may bring lead dust into the home *(435)*.

No safe level of exposure to lead has been identified and even at low levels of exposure lead can cause a wide range of toxic effects. Exposure to lead can increase blood pressure *(437)*, which is the most important risk factor for cerebrovascular disease. Based on 2015 data, lead exposure is estimated to account for 12.4% of the global burden of idiopathic intellectual disability, 2.5% of the global burden of IHD, 2.4% of the global burden of stroke, 4.4% of hypertensive heart disease, 0.8% of rheumatic heart disease and 1.4% of other cardiovascular diseases worldwide *(438)*. Exposure to lead has also been linked to chronic kidney diseases in various settings *(439–441)*. Exposure to lead is estimated to have caused 853 000 deaths in 2013 *(22)*.

Young children are particularly vulnerable to lead because they absorb four to five times as much ingested lead as adults from a given source. Moreover, children's innate curiosity and their age-appropriate hand-to-mouth behaviour result in their mouthing and swallowing lead-containing or lead-coated objects *(435)*. At high levels, lead attacks children's brain and central nervous system to cause coma, convulsions and even death *(435)*. Exposure to even low levels of lead during childhood has been associated with attention deficit disorder and neurodevelopmental disorders, including reduced intelligence quotient *(442–444).*

8.6.1 WHO Guidelines and recommendations for lead

WHO has issued guideline values for lead in drinking-water (2011) and in air (2000), and a set of recommendations to prevent childhood lead poisoning, including some recommendations related to housing as listed below.

WHO Air quality guidelines for Europe (second edition) (2000)[24]
Air quality guideline value for lead
The annual average lead level in air should not exceed 0.5 μg/m³. To prevent further increases in the exposure of future generations, air lead levels should be kept as low as possible.

WHO Guidelines for drinking-water quality (fourth edition) (2011)[25]
Drinking-water quality guideline value for lead
The *WHO Guidelines for drinking-water quality* have set a provisional guideline value of 0.01 mg/l (10 μg/l). For details, see section 8.1.

24 Source: http://www.euro.who.int/__data/assets/pdf_file/0005/74732/E71922.pdf?ua=1
25 Source: http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/

Exposure to lead: a major public health concern (2010)[26]

Recommendations on elimination of use of lead[27]

- Phase out the use of lead in paints on a worldwide basis.
- Eliminate the use of leaded solder in food and drink cans, as well as in water pipes.
- Eliminate the use of lead in homes, schools, school materials and children's toys.
- Eliminate the use of lead glazing for pottery intended for cooking, eating or drinking.
- Encourage the removal of plumbing and fittings containing lead (as this is costly, other measures, such as corrosion control and minimizing the dissolving of lead in water systems, should be implemented in the meantime).

8.7 Radon

Exposure to radon gas in the home and workplace is one of the main sources of exposure to ionizing radiation. Radon is a colourless, odourless gas, and is radioactive with a half-life of 3.8 days, decaying by the emission of alpha particles. Other major source comes from building materials through exposure to gamma radiation from radionuclides ^{226}Ra and ^{232}Th and their progeny, and ^{40}K *(445)*, as well as occupying housing built in areas where radon has previously been mined *(446)*.

In 2010, there were 98 992 deaths and 2.1 million DALYs attributable to residential radon exposure worldwide *(447)*. An assessment on the environmental burden of disease associated with inadequate housing in the WHO European Region (2011) indicates that radon exposure is associated with more than 3000 deaths per year in the three countries of France, Germany and Switzerland, with death rates per 100 000 ranging from 2.1 (France) to 3.2 (Switzerland) *(448)*.

26 Source: http://www.who.int/ipcs/features/lead..pdf

27 Although there is no WHO guideline, it should be mentioned that the United States of America has a standard for lead in settled dust which is the main source of exposure for most children. It should also be mentioned that there are documents for safe and effective methods of lead-based paint hazard control. The *US Guidelines for the evaluation and control of lead-based paint hazards*, US Department of Housing and Urban Development, 2012, for both the exposure limits and work practice standards, are a key reference.

8.7.1 WHO Handbook on indoor radon (2009)[28]

The *WHO Handbook on indoor radon* includes practical guidance on radon management considered relevant for the *WHO Housing and health guidelines*.

Radon prevention and mitigation measures
Addressing radon is important both in construction of new buildings (prevention) and in existing buildings (mitigation or remediation). The primary radon prevention and mitigation strategies focus on sealing radon entry routes, on ventilation and on reversing the air pressure differences between the indoor occupied space and the soil underneath the building, employing different soil depressurization techniques. In many cases, a combination of strategies provides the highest reduction of radon concentrations. In the quest for improved home energy efficiency, changes to ventilation need to be carefully evaluated to avoid enhanced indoor exposure to radon and risk of lung cancer.

National radon policies and related public health programmes
A national radon policy should focus on identifying geographic areas where populations are most at risk from radon exposures and raising public awareness about the associated health risk. Key elements for a successful national programme include collaboration with other health promotion programmes (e.g. indoor air quality, tobacco control) and training of building professionals and other stakeholders involved in the implementation of radon prevention and mitigation.

Appropriate building codes that require the installation of radon prevention measures in homes under construction should be enacted, and the measurement of radon during the purchase and sale of homes is useful to identify those with high radon concentrations.

Public health programmes to reduce the radon risk should be ideally developed at national level and include regional and local organizations to support implementation. Such national radon programmes would be designed to reduce the overall population's risk from the national average radon concentration as well as the individual risk for people living with high radon concentrations.

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28 Source: http://apps.who.int/iris/bitstream/10665/44149/1/9789241547673_eng.pdf

National reference levels for radon

A national reference level for radon defines a level of risk from indoor radon that a country considers to be too high if it continues unchecked in the future. It is an important component of a national programme. For homes with radon concentrations above this level remedial actions may be recommended or required. When setting a reference level, various national factors, such as the distribution of radon, the number of existing homes with high radon concentrations, the arithmetic mean indoor radon level and the prevalence of smoking, should be taken into consideration. In view of the latest scientific data, WHO proposes a reference level of 100 Bq/m^3 to minimize health hazards due to indoor radon exposure.[29] However, if this level cannot be reached under the prevailing country-specific conditions, the chosen reference level should not exceed 300 Bq/m^3, which represents approximately 10 mSv per year according to calculations by the International Commission on Radiological Protection.[30]

Cost–effectiveness of radon interventions

The choice of radon prevention and mitigation interventions can be based on an analysis of cost–effectiveness. In this approach, net health care costs are set in relation to net health benefits for a variety of actions or policies, providing an index with which these actions can be prioritized.

Selected analyses indicate that preventive measures in all new buildings are cost-effective in areas where more than 5% of current dwellings have radon concentrations above 200 Bq/m^3. Prevention in new homes tends to be more cost-effective than mitigation of existing homes. In some low-risk areas the measurement costs may be higher than the mitigation costs (for existing dwellings) due to the high number of homes that will have to be tested compared with the proportion of homes mitigated. Even if analyses indicate that remediation programmes may not be cost-effective on a nationwide basis, remediation should be undertaken in areas of high radon concentrations.

29 The *WHO Handbook on indoor radon* focuses on risk management and thus provides a reference level for action as described above. However, as radon is a carcinogen, there is no safe threshold level (see section 8.2.1).

30 The International Commission on Radiological Protection is currently revising its reference dose coefficients for inhalation and ingestion of radon isotopes and progeny, which relate indoor radon concentrations (in Bq/m^3) to annual effective dose (in mSv/y).

8.8 Additional WHO guidance related to housing

In addition to the above summaries of guidelines and recommendations, a wide range of WHO reports address environmental and health issues related to housing, or built environments in general and provide various forms of guidance. This guidance can be derived from research evidence as well as practical experience and intervention reviews. The list below, with links to WHO reports and documents, provides further information for researchers, practitioners and stakeholders in relation to specific topics.

Technical guidance documents by WHO

Global report on urban health: equitable, healthier cities for sustainable development (WHO/UN-Habitat, 2016):
http://www.who.int/kobe_centre/measuring/urban-global-report/ugr_full_report.pdf

World report on ageing and health (WHO, 2015):
http://apps.who.int/iris/bitstream/10665/186463/1/9789240694811_eng.pdf

World report on disability (WHO, 2011):
http://www.who.int/disabilities/world_report/2011/en/

Public health advice on preventing health effects of heat (WHO Regional Office for Europe, 2011):
http://www.euro.who.int/__data/assets/pdf_file/0007/147265/Heat_information_sheet.pdf

Environmental burden of disease associated with inadequate housing – summary report (WHO Regional Office for Europe, 2011):
http://www.euro.who.int/__data/assets/pdf_file/0017/145511/e95004sum.pdf

Childhood lead poisoning (WHO, 2010):
http://www.who.int/ceh/publications/leadguidance.pdf

Natural ventilation for infection control in health-care settings (WHO, 2009):
http://www.who.int/water_sanitation_health/publications/natural_ventilation.pdf

Essential environmental health standards in health care (WHO, 2008):
http://www.who.int/water_sanitation_health/hygiene/settings/ehs_health_care.pdf.pdf

World report on child injury prevention (WHO, 2008):
http://www.who.int/violence_injury_prevention/child/injury/world_report/en/

Public health significance of urban pests (WHO Regional Office for Europe, 2008):
http://www.euro.who.int/__data/assets/pdf_file/0011/98426/E91435.pdf

Global age-friendly cities: a guide (WHO, 2007):
http://www.who.int/ageing/publications/Global_age_friendly_cities_Guide_English.pdf

Pesticides and their application – for the control of vectors and pests of public health importance (sixth edition) (WHO, 2006):
http://apps.who.int/iris/bitstream/10665/69795/1/WHO_CDS_NTD_WHOPES_GCDPP_2006.1_eng.pdf

Framework for developing health-based EMF standards (WHO, 2006):
http://www.who.int/peh-emf/standards/framework/en/

Guidelines for vulnerability reduction in the design of new health facilities (PAHO, 2004):
http://www1.paho.org/English/DD/PED/VulnerabilityReduction.pdf

Guidelines on the prevention of toxic exposures (WHO/UNEP/ILO, 2004):
http://www.who.int/ipcs/features/prevention_guidelines.pdf

Health impact of low indoor temperatures. Report on a WHO meeting, Copenhagen, 11–14 November 1985 (WHO, 1987):
http://www.theclaymoreproject.com/uploads/associate/365/file/Health%20Documents/WHO%20-%20health%20impact%20of%20low%20indoor%20temperatures%20(WHO,%201985).pdf

Policy-related guidance documents by United Nations agencies

New Urban Agenda (UN-Habitat, 2016):
http://habitat3.org/the-new-urban-agenda/

International guidelines on urban and territorial planning (UN-Habitat, 2015):
http://unhabitat.org/books/international-guidelines-on-urban-and-territorial-planning/

The Geneva UN Charter on Sustainable Housing (UNECE, 2015):
https://www.unece.org/fileadmin/DAM/hlm/documents/Publications/UNECE_Charter_EN.pdf

The right to adequate housing (OHCHR/UN-Habitat, 2009):
http://unhabitat.org/the-right-to-adequate-housing-fact-sheet-no-21rev-1/

The right to healthy indoor air (WHO Regional Office for Europe, 2000):
http://www.euro.who.int/__data/assets/pdf_file/0019/117316/E69828.pdf

Istanbul Declaration on Human Settlements (UN-Habitat, 1996):
http://www.un.org/ga/Istanbul+5/declaration.htm

The Universal Declaration of Human Rights, Article 25 (UN, 1948):
http://www.un.org/en/universal-declaration-human-rights/

IAEA Safety standards for protecting people and the environment (IAEA/WHO, 2015):
http://www-pub.iaea.org/MTCD/publications/PDF/Pub1651Web-62473672.pdf

9

Implementation of the WHO Housing and health guidelines

9 Implementation of the WHO Housing and health guidelines

The purpose of the HHGL is to provide evidence-informed recommendations on how to achieve optimal housing standards that promote the health and well-being of occupants. While the GDG deems the access to safe and healthy housing a right for populations across all Member States, it also acknowledges that implementing these recommendations will be challenging and vary according to a country's context *(449)*. Therefore, the global guidance referring to structural aspects of healthy housing provided by these guidelines needs to be considered in the context of national and local priorities relating to the feasibility, acceptability, need and resources for implementing single recommendations. As such, successful implementation will require coordination between national, regional and local governments, and intersectoral collaboration between public, private and civil society actors, including implementing partners such as architects, urban planners, social housing services, consumer protecting agencies, and the building industry. Interventions reducing health risks from poor housing include direct changes to the built environment as well as the introduction of loans and subsidies to support these changes to the structural housing environment.

The implementation of housing standards also needs to take into consideration the life cycle of dwellings, i.e. construction of new buildings, inhabitation, renovation and demolition. Housing risks can also have an impact on health at different moments of a building's life. Examples here are the use of asbestos and lead, as outlined in sections 8.5 and 8.6. Although the production and the control and management of asbestos during building retrofits and demolition is controlled, it is still a potential threat to health during habitation, and especially during the clean-up of damaged and destroyed buildings (e.g. after disasters such as tsunamis and earthquakes), and not only in low-income countries. The life course of the building is therefore an important dimension to be considered during the implementation of the guidelines, especially as some health-relevant guidance presented in the HHGL may not be implementable in some of the existing housing stock, or only at high cost.

Implementation of the guidelines will further vary depending on the geographical location of a country. While in some climate zones, a priority might be to protect people from excess indoor heat; in other regions the protection from indoor cold might be more important. As climate change is expected to reinforce the occurrence of extreme weather events and impact a country's climatic conditions, the availability of safe and healthy housing offering protection from the consequences of climate change will become even more important. In addition, the socioeconomic circumstances of a country need to be taken into account. While there is growing evidence that the recommended interventions are cost-effective and cost-beneficial (see section 9.3), retrofitting existing housing or building a new housing stock adhering to the guidelines at large scale demands significant financial investment from governments, including subsidies to support communities and individual home owners in implementing new housing standards. Accordingly, the national implementation strategy needs to carefully assess the country's needs and resources and accordingly prioritize those interventions that are the most feasible, appropriate and highly valued in the specific country context.

As the HHGL provide global guidance, they need to be adapted to the local context to best meet a country's priorities and needs. WHO will provide technical assistance to its Member States for context-specific implementation of the HHGL. This will be done through joint efforts at all three levels of the organization and in close collaboration with other United Nations agencies involved in housing activities. A modular toolkit supporting the guidelines' implementation at country-level is currently under development. This tailored implementation assistance will comprise tools to facilitate priority setting, needs assessment, stakeholder mapping, policy analysis, intersectoral dialogue, and outreach and advocacy activities. As implementation teams will be interdisciplinary, the toolkit will include various knowledge translation products, such as policy briefs and training materials, to enable intersectoral collaboration and mutual understanding.

9.1 Health in All Policies and housing

Housing interventions can represent a major opportunity to promote "primary prevention" through intersectoral action. The Health in All Policies approach emphasizes that ministries of health must act as stewards in other sectors to ensure that health objectives are considered in their policies *(450)*. This includes advocating to promote access to social housing for vulnerable groups, ensuring standards for housing, and empowering vulnerable groups to enhance their security and ownership. To date, many ministries of health have not engaged fully with the health impacts of housing, in part because housing is often considered to be the responsibility of other departments of government, rather than health.

Implementing the HHGL entails different responsibilities for authorities, owners and occupiers in different Member States. Countries have distinctive administrative and legal environments, which may include central government departments, state departments, regional authorities or local authorities (municipalities). In some countries, responsibility for housing is spread across a number of government departments, including housing, construction, energy, urban planning, transport, public health, finance, industry and environment. In addition, policies in other departments affect housing supply and affordability, including those on immigration, wages and benefits, workforce training, and tax and monetary policy.

The HHGL demonstrate the interlinkages between housing and health and can serve as a starting point for ministries of health to work with other ministries to initiate policy processes to improve national and local housing standards. Effective policy coordination between government departments is therefore a critical step in implementing the HHGL.

This may include advocating for the importance of healthy housing and communicating potential health harms and benefits through closer involvement in housing assessments and building and renovation codes. In particular, the health sector can work to ensure that proposed housing interventions avoid harms and improve health and safety. It can identify individuals and households that could most benefit from housing assessments and interventions.

Implementing the HHGL is also an opportunity to strengthen the health sector's engagement with the community, so as to generate a space for primary environmental action and to propose a political perspective that enables governmental organizations, nongovernmental organizations, communities, households, businesses and individuals to be part of the strategic planning, active monitoring and social control in the decision-making process and in the management of the healthy housing strategy. This may involve health advocates being represented in decision-making forums regarding construction and planning. WHO will work with ministries of health to support this role, and to ensure that health perspectives are strongly represented in policies related to housing. The implementation toolkit will provide training materials to promote such intersectoral dialogue and bring healthy housing to the agenda of policy-makers inside and outside the health sector.

9.2 Co-benefits from multifactorial interventions

The HHGL draw on systematic reviews of research that assessed the impact of specific exposures or interventions on health outcomes. This meant that some studies were not eligible for the systematic reviews because they reported the results of multifactorial interventions. Such interventions aim to address a number of housing risks at the same time, and sometimes seek to impact on other risks as well (e.g. to improve physical or mental functioning through exercise). While such multi-factorial interventions cannot ascribe a particular health effect to a particular part of the intervention, they can improve a range of health outcomes. Two illustrative examples are provided in Box 1.

Box 1

The Healthy Housing Programme in South Auckland, New Zealand, as a direct response to a type-B meningococcal disease epidemic, sought to reduce injuries, improve insulation and ventilation, and reduce crowding. This was found to be an efficient and cost-effective way of addressing multiple health risks at the same time, and there was a significant reduction in acute hospitalization for people aged under 34 years compared with the period before the multifactorial intervention *(451)*.

The "breathe-easy homes" at High Point, Seattle, United States of America, were designed to reduce exposure to a range of environmental asthma triggers, using moisture-reduction features, enhanced ventilation systems, and materials that minimized dust and off-gassing. These measures reduced exposures to mould, rodents and moisture, and residents of the breathe-easy homes had more asthma-symptom-free days than previously after living for 1 year in the homes. The proportion of residents with an urgent asthma-related clinical visit in the previous 3 months decreased from 62% to 21% *(452)*.

One study assessed the effects of providing upgraded housing to slum dwellers in El Salvador, Mexico and Uruguay *(453)*. The upgraded housing had tin roofs and was made of insulated pinewood panels or aluminium, and was aimed at keeping occupants warm and protected from humidity, insects and rain. In addition, floors were raised above the ground to reduce dampness and protect occupants from floods and infestations. The housing therefore addressed a range of housing risk factors, and constituted a major improvement over other housing units in the informal settlements, which are typically constructed from poor materials such as cardboard and plastic, and have dirt floors. The analysis showed that people in households provided with upgraded housing were happier and more satisfied with the quality of their lives as compared with the control group. In El Salvador and Mexico, the analysis also showed improvements of child health.

When implementing the HHGL it will be helpful to take a multifactorial approach, addressing multiple risk factors at the same time in order to achieve a range of health benefits in the most efficient manner possible. This approach can reduce costs while improving health, and is consistent with the way housing improvements are often carried out. In addition, understanding the complex interactions associated with housing risk and interventions protects against unanticipated consequences, such as the decrease in indoor air quality associated with some early efforts to improve insulation in housing *(454)*.

Currently, in some places, housing code inspectors or building assessors are often deployed based on a specific complaint, such as lack of heating or structural instability, and frequently only order corrections for that one violation of the building code. Similarly, health inspectors who examine housing conditions are often focused on specific issues, such as potable water and sewage, radon, lead or asbestos *(358, 455, 456)*. Alternative regulatory approaches identify and treat multiple housing deficiencies that are often located within the same housing. Examples of the multifactorial approach include the English Housing Health and Safety Rating System, the United States National Healthy Housing Standard and the New Zealand Rental Warrant of Fitness *(353–355)*. This approach can sometimes enable otherwise separate funding streams to be integrated, including, for example, funds intended to encourage energy efficiency and community development.

Such an approach is particularly suitable given that housing deficiencies often have the same root causes that together are associated with poor health outcomes. For example, excessive moisture can be simultaneously associated with: asthma and other respiratory conditions, due to increased exposure to mould; lead poisoning, due to paint failure; injuries, due to structural rot; increased exposure to pests such as cockroaches; and increased infiltration of radon from concrete, shale and soil *(246, 457, 458).* Thus, correction of moisture problems can lead to a variety of improvements in health outcomes via a variety of pathways. Similarly, correcting structural defects reduces the risk of injury, improves thermal temperature and reduces exposure to outdoor pollutants. The clear relationships between housing conditions and multiple different health risks, outlined in Chapter 1, emphasize that interventions can often easily and efficiently address multiple health risks at the same time. Therefore, policy-makers should have the co-benefits of multifactorial interventions in mind when enacting new regulations or subsidizing home modifications to maximize the efficiency of such policy interventions. The implementation toolkit will contain a repository of multifactorial interventions and their benefits, to facilitate evidence-informed decision-making by policy-makers.

9.3 Economic considerations for improving housing conditions

A recent systematic review highlights considerable evidence on the cost-effective health benefit of several housing interventions in several populations and country settings. For example, the five reviewed studies on lead removal for reducing lead poisoning showed that it was very cost-effective *(459–463)*, and three studies on retrofitting insulation found that this was also highly cost-beneficial *(40, 464, 465)*. An analysis of the New Zealand insulation subsidy programme reviewed in Chapter 4 showed that the benefits in savings to the health systems outweighed the cost of administrating and subsidizing the insulation scheme by almost 4 to 1, with higher benefit to cost ratios of 6 to 1 for children and older people *(40)*; an earlier analysis with a smaller sample, and including energy savings and productivity benefits, found a benefit to cost ratio of 2 to 1 *(464)*. Most analyses of home safety modification interventions have found these to be cost-effective *(26, 359–366)*. For example, benefits outweighed costs in the cluster randomized trial of the impact of home modifications on falls in the New Zealand study reviewed in Chapter 6 *(71)*. Drawing on insurance payments for medically treated home fall injuries, the benefits in terms of the value of DALYs averted and social costs of injuries saved outweighed the intervention by 6 to 1. The benefit–cost ratio can be at least doubled for older people and increased by 60% for those with a prior history of fall injuries *(71)*.

A WHO cost–benefit analysis showed that improvements in water and sanitation access were cost-beneficial across all regions. In developing regions, the return on a US$ 1 investment was in the range US$ 5 to US$ 46, depending on the intervention. For the least developed regions, every US$ 1 invested to meet the combined water supply and sanitation Millennium Development Goals led to a return of at least US$ 5 (AFR-D, AFR-E, SEAR-D) or US$ 12 (AMR-B; EMR-B; WPR-B) (the letters refer to WHO subregional country groupings based on similar rates of child and adult mortality) *(466)*. An analysis of water supply improvements in Manila, Philippines, found that improvements in water supply supported household finances, as residents were able to reallocate time saved in collecting water to income-generating activities *(467)*. The Piso Firme programme replaced dirt floors with cement floors in some Mexican cities. Comparison of a control and treatment city showed that the programme significantly improved the health of young children, with a decreased incidence of parasitic infestations, diarrhoea, and the prevalence of anaemia, and a significant improvement in children's cognitive development. People with cement floors reported improved satisfaction with housing, and reductions in self-assessed depression and stress scales. The authors found that the intervention was a more cost-effective policy for improving child cognitive development than Mexico's cash transfer programme *(468)*.

Multifactorial interventions have also been shown to be a good investment. For example, the South Auckland, New Zealand, multifactorial intervention found that reducing crowding, connecting housing occupants with health and social services, and improving housing quality reduces hospitalization rates, and had a positive benefit to cost ratio of 1.15 *(451)*. A systematic review of multicomponent interventions aimed at reducing asthma morbidity concluded that these are a good investment, with each US$ 1 invested yielding US$ 5–14 in benefits *(469)*. Since that review was carried out in 2011, further United States of America studies have shown that asthma home interventions yielded returns on investment of 1.90 *(470)*, 1.46 *(471)* and 1.33 *(472)*. In the United Kingdom, it has been estimated that reducing the number of dwellings where there are serious "category 1" hazards present (as defined under the Housing

Health and Safety Rating System, these include faulty wiring and boilers, very cold bedrooms, leaking roof, mould, pest infestation, broken steps, or lack of security due to badly fitting external doors or problems with locks) to an acceptable level would cost £10 billion, but the consequent improvements in occupant health would save the United Kingdom health services £1.4 billion in first-year treatment costs alone, allowing the investment to pay for itself in 7 years *(240)*. In the European Union, it has been estimated that for every €3 invested in improving housing conditions, €2 would be recouped in 1 year from savings on health care and publicly funded services *(473)*.

9.4 Training needs

Implementing the HHGL requires the training of a number of stakeholders. Health department professionals need evidence-based training and technical assistance programmes to help target communities living in substandard housing conditions and to provide solutions to combat hazards in their homes. The housing sector (in particular, housing agencies), need specialized training and technical assistance programmes to identify housing problems, to build better housing, and to remediate existing housing. Health and housing professionals have unique expertise to share, and cross-sector collaboration should be encouraged. The health and safety of workers involved in housing construction and remediation, as well the occupants of that housing, is imperative *(247)*.

As part of the comprehensive implementation strategy, WHO and its partners will provide hands-on guidance and information tools, technical assistance, and training in order to help drive positive changes in health and housing policy and practice at the federal, state and local levels.

9.5 Dissemination

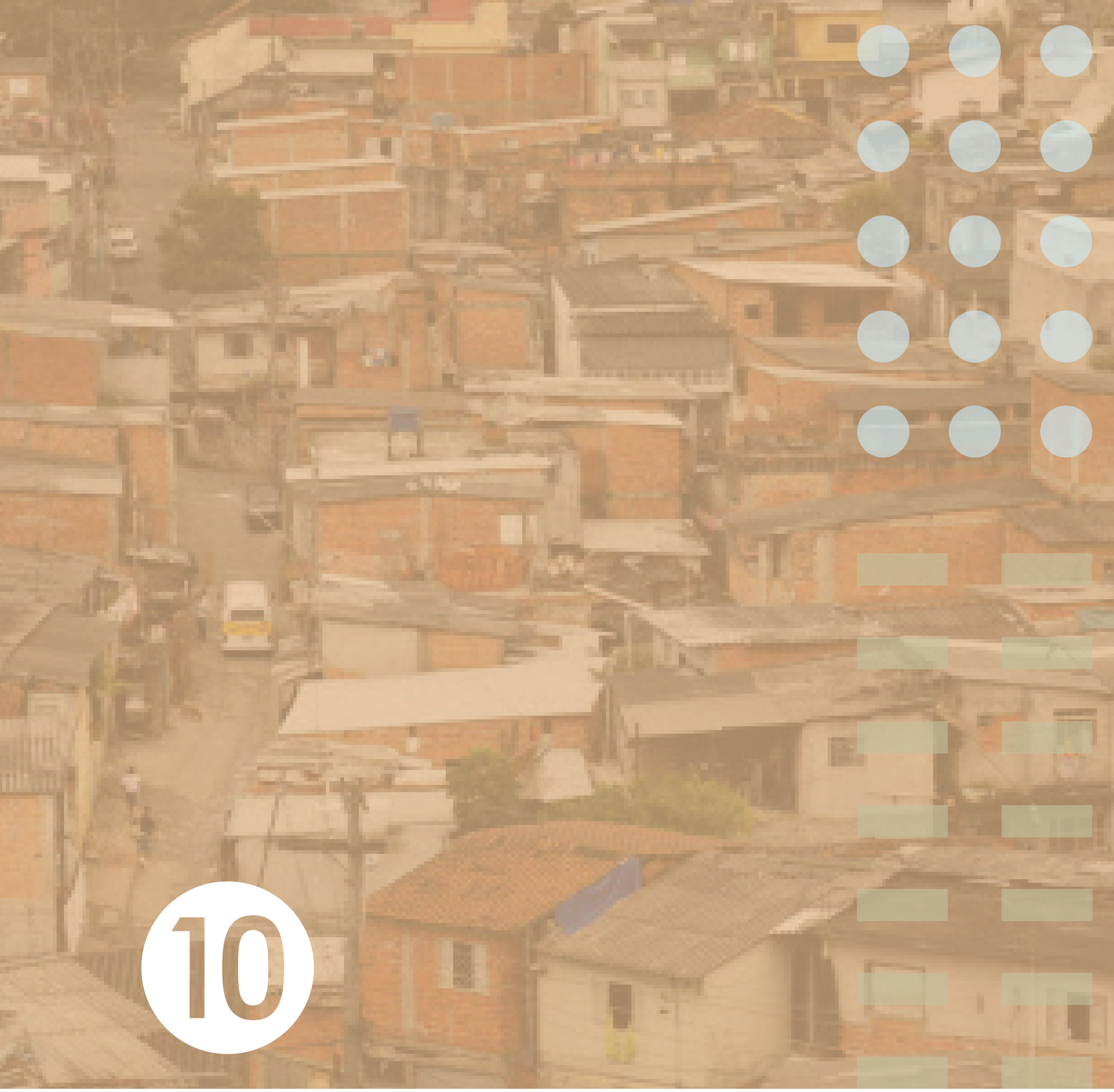
The HHGL recommendations will be disseminated with the co-operation of a broad network of international partners, including: WHO country and regional offices; ministries of health; ministries of building and construction; WHO collaborating centres; other United Nations agencies, particularly the United Nations Human Settlement Programme (UN-HABITAT); and nongovernmental organizations. They will also be available on the WHO website. In addition, an executive summary and other outreach materials aimed at staff in the health, building and planning sectors, and a wide range of policy-makers and programme managers, will be developed and disseminated through WHO country offices and their respective partners. Technical support for the adaptation and implementation of the HHGL in countries will be provided at the request of ministries of health or WHO regional or country offices.

9.6 Monitoring and evaluation: assessing the impact of the guidelines

Health gains will only be achieved if healthier and safer housing building materials, practices and principles are used widely, and if housing is maintained properly and replaced when necessary. Active monitoring and evaluation of the HHGL are therefore vital. Understanding where and to what extent the HHGL are implemented will provide insight into the distribution of progress arising from them, as well as an indication of their impact. A housing quality surveillance system, similar to a public health system, should be considered by Member States.

One way to monitor the impact of the HHGL will be to apply the environmental burden of disease approach to the healthy homes field. The *Environmental burden of disease associated with inadequate housing: a method guide to the quantification of health effects of selected housing risks in the WHO European Region* (2011), provides a methodological basis to be adopted at the global scale as well as extended to several additional risk factors. As the selection of the housing factors considered in the report was based primarily on whether the relevant data are available and amenable to the environmental burden of methodology, some of the potential risks from inadequate housing were not covered. However, because data availability has increased in recent years, the methodology could be expanded to those housing risk factors covered by the HHGL.

The impact of the HHGL can be evaluated within countries (i.e. monitoring and evaluation of the programmes implemented at national or regional scale) and across countries (i.e. adoption of the HHGL globally). The implementation toolkit will comprise guidance on monitoring and evaluation activities for integration into ongoing data collection processes, to avoid an additional burden on statistics offices and reporting bodies.



10

Updating and expanding the guidelines

⑩ Updating and expanding the guidelines

The recommendations in the HHGL will be updated after 5 years as more evidence becomes available (e.g. on indoor heat exposure). WHO and partners intend to seek funds to work with key partners to:

- address interventions that were not reviewed for the HHGL;
- prioritize research questions addressing the research gaps indicated in this report; and
- determine the most effective methods for studying the prioritized questions.

The update will focus in particular on adding recommendations on key housing risk factors not covered by this edition (e.g. access to green spaces in the immediate housing environment, access to walking and cycling infrastructure, housing interventions that protect from vector-borne diseases and pests, ventilation), as well as providing recommendations on multifactorial interventions.

As defined in the introduction to these guidelines, the housing definition also comprises the immediate housing environment, or the setting around people's home where they carry out their day-to-day activities. The way the immediate environment, as a composite of several features including the streets on which homes are located as well as the recreational facilities, sources of foods (markets and food stores), open spaces, parks, and natural amenities available in proximity to homes, is shaped critically impacts health. Urban and landuse planning are therefore key public health determinants that would benefit from further evidence-based guidance.

Further recommendations might also look at the relation between health and other aspects of housing such as security of tenure, residential mobility, humidity, structural integrity, and the accessibility of housing to public transport, bicycle-friendly streets, walkable neighbourhoods, shops and other community resources.

Through the HHGL, WHO has the potential to continue to support Member States in their efforts to close the health equity gap through promoting healthy housing and urban conditions and to contribute to efforts to reduce global poverty. Guidance will be developed engaging with housing, planning, settlement development sectors, inhabitants, and nongovernmental organizations to support them to prioritize actions on housing and health in slums and other informal settlements. It will comprise advice on key threats to health in slums and on best health prevention and promotion practice. It will advise on how to prioritize actions and how to implement the HHGL, as well as providing guidance on interventions.

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