World Health Organization

KEEPING THE VECTOR OUT

Housing improvements for vector control and sustainable development

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Keeping the vector out: housing improvements for vector control and sustainable development

ISBN 978-92-4-151316-6

Suggested citation. Keeping the vector out: housing improvements for vector control and sustainable development. Geneva: World Health Organization; 2017. Licence: CC BY-NC-SA 3.0 IGO.

Cataloguing-in-Publication (CIP) data. CIP data are available at http://apps.who.int/iris.

Editorial consultant: Vivien Stone, Etchingham, UK.
Photo cover ©: Konstantin Ikonomidis.
Design and layout: L'IV Com Sàrl, Villars-sous-Yens, Switzerland.
Printed by the WHO Document Production Services, Geneva, Switzerland.

Contents

Acknowledgements

This policy brief was written by Christian Kraef, under the guidance of Nathalie Röbbel (WHO, Department of Public Health, Environmental and Social Determinants of Health). It was developed in close collaboration with WHO's internal and external partners. Key contributors and reviewers were Graham Alabaster (UN-Habitat), Sophie Boisson (WHO), Jennifer De France (WHO), Elaine Fletcher (WHO), Bruce Gordon (WHO), Jan Kolaczinski (WHO), Axel Kroeger (Centre for Medicine and Society, University of Freiburg, Germany), Annette Kuesel (WHO), Steven Lindsay (Durham University, United Kingdom), Martha Quinones Pinzon (WHO), Lucy Tusting (University of Oxford, United Kingdom), Raman Velayudhan (WHO) and Eugenio Villar (WHO).

Acronyms and abbreviations

DDT	dichlorodiphenyltrichloroethane
IVM	integrated vector management
RBM	Roll Back Malaria Partnership
SDGs	Sustainable Development Goals

Key messages

- **More than 80% of the world's population is at risk** from at least one vector-borne disease, and more than half at risk from two or more. Malaria alone accounts for around 429 000 deaths annually, while close to 100 million fall ill with dengue every year. These, and other vector-borne diseases, account for 17% of the global burden of all infectious diseases and impede economic development, well-being of populations and prosperity. These diseases disproportionally affect the poor.
- WHO and its Member States recognize the need for implementation of relevant vector control interventions that go beyond the health sector and **strengthen multisectoral approaches – with housing being a key part of the global response**.
- The evidence shows that **poor quality housing and neglected peri-domestic environments are risk factors** for the transmission of malaria, arboviral diseases (e.g. dengue, yellow fever, chikungunya, Zika virus disease), Chagas disease and leishmaniasis.
- **It is time** to highlight the role improving human habitation can play in the fight against vector-borne diseases. The movements of populations, the rapid urbanization of the 21st century and the economic development experienced in many low- and middle-income countries are drivers for the construction of new housing and the planning and redesign of urban settlements. At the same time, inequities in power and wealth fuel the growth of slums and informal settlements.
- The principle of **"building the vector out"** is at the core of effective housing interventions to prevent vector-borne diseases. The entry of disease-transmitting vectors into human habitation can be effectively prevented by screening windows, doors and eaves of houses, by fitting ceilings, and by reducing the vectors' indoor hiding and breeding places, such as cracks and crevices in walls, floors and roofs. Such building strategies need to be accompanied with improved ventilation, to keep the occupants cool in hot climates, and increased use of insecticide-treated nets.
- In addition, **reducing breeding sources** around houses can limit vector abundance – by removing sources of stagnating water (e.g. gutters and drains) and minimizing access to water storage containers through the use of covers or screens. Key to this is a reliable supply of piped water, adequate sanitary facilities, rainwater disposal and services to safely manage faecal wastes. However, preventing vectors from accessing or breeding in water storage containers may not always be possible or fully effective. In such circumstances, using larvicides may be considered, including for drinking-water storage.[1]
- These interventions may help **reduce morbidity, mortality, human suffering** and thereby promote economic growth, well-being and the reduction of poverty. Creating sustainable vector-proof habitats and establishing a comprehensive management plan can help reduce the dependence on insecticides (thereby helping to manage insecticide-resistance) and bring about sustainable change – vital to prevent the re-introduction into disease-free areas.
- **A number of eco-benefits** are associated with positioning these interventions at the core of integrated vector management. A reliable and safe piped water supply can support the reduction of waterborne diseases. Improving housing can also create jobs and stimulate investment. Addressing health risks associated with housing is likely to particularly benefit low-income and vulnerable groups, as these are more likely to live in inadequate housing. Furthermore, involving housing ministries and other housing actors can yield additional capacities and financial resources

[1] The WHO Prequalification Team, and, previously, the WHO Pesticide Evaluation Scheme (WHOPES), coordinates the testing and evaluation of pesticides used for public health. There are currently seven larvicidal compounds listed for the control of container-breeding mosquitoes. Further information can be found at: http://www.who.int/whopes/Mosquito_larvicides_25_April_2017.pdf?ua=1 and in the WHO Guidelines for drinking-water quality at: http://www.who.int/water_sanitation_health/water-quality/guidelines/en/

Introduction

Vector-borne diseases are responsible for 17% of the global burden of communicable diseases and more than 500 000 deaths annually. The ambitious global targets for the control of vector-borne diseases come in the context of the (re-)emergence of diseases, increasing resistances to insecticides and uncertainty related to the financing of global vector control efforts.

The United Nations 2030 Agenda with its related Sustainable Development Goals (SDGs), the New Urban Agenda adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito in 2016 and WHO's Global vector control response 2017–2030 (WHO, 2017a) emphasize the value of elevating multisectoral actions and strategies that extend beyond the health sector to the core of integrated vector control.

This policy brief underlines the important role housing conditions have in the transmission of vector-borne diseases and showcases interventions and policies the housing sector can contribute to effective, integrated and intersectoral vector-borne diseases management.[1]

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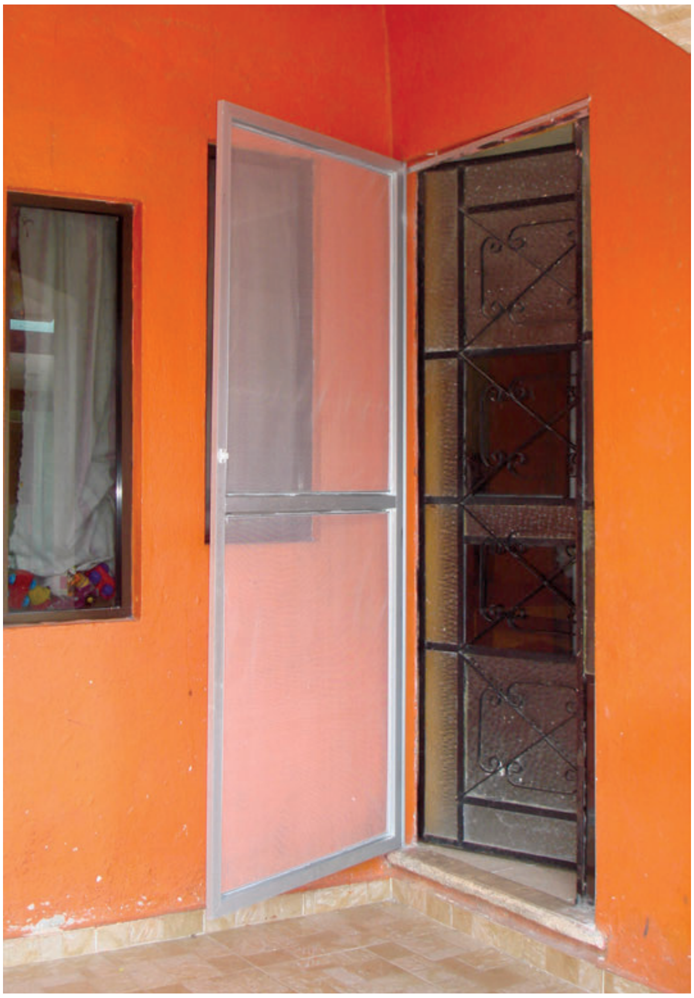

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[1] While the focus of this brief is on housing interventions, such interventions would still need to be planned within the context of a larger community environmental management strategy for vector control (management of neighbourhood waste and waste containers, community water storage tanks and rainwater/sewage flows, etc.) (Campbell-Lendrum D et al, 2005). In peri-urban and rural areas, animal pens and corrals are also important. This includes pigsties, chicken dens, goat corrals and cow stables, as animals may continue to serve as "hosts" for vector breeding and thus disease transmission.

Political and socioeconomic contexts

Recent political developments have created a window of opportunity for strengthening the role of housing interventions in the fight against vector-borne diseases. The international community has recognized the need to tackle the challenges to human development through multisectoral approaches. The 2015, **Sustainable Development Agenda** called for action by all countries to achieve the 17 interlinked SDGs. One of the targets for SDG 3 (good health and well-being) is to end the epidemics of malaria and neglected tropical diseases, which include vector-borne diseases such as Chagas disease, leishmaniasis, dengue, Zika and chikungunya. The achievement of this target depends on – and enables – concomitant progress on SDG 1 (no poverty), SDG 6 (clean water and sanitation), SDG 8 (decent work and economic growth), SDG 10 (reduced inequalities), SDG 11 (sustainable cities and communities), SDG 13 (climate action) and SDG 17 (partnership).

In addition, the **New Urban Agenda** was adopted at the third United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito in 2016. By addressing the way human settlements are planned, designed, financed, legally approved, developed, governed and managed, it aims to make cities inclusive, safe, resilient and sustainable. The New Urban Agenda contains a strong commitment to promoting healthy urban environments, free from natural hazards. It emphasizes the important role of cities, towns and human settlements in ending the epidemic of malaria and adapting to climate change-related threats such as vector-borne diseases.

Recently, WHO and its Member States have underlined the need to reposition vector control as a cornerstone in the fight against vector-borne diseases by adopting the **Global vector control response 2017–2030** at the World Health Assembly in May 2017 (WHO, 2017a). The recent alarming increase in arboviral diseases, paired with the emerging threat of insecticide resistance, have demonstrated the limitations of narrow, health sector focused programmes and reinforced the need for a multisectoral approach – with housing being a key sector.

Integrated vector management (IVM) – a rational decision-making process for the optimal use of resources for vector control – is at the core of the WHO approach to vector control (WHO, 2012a). Further relevant documents include:

- **WHO Global technical strategy for malaria 2016–2030** (WHO, 2015);
- **WHO A framework for malaria elimination 2017** (WHO, 2017b);
- **WHO Global strategy for dengue prevention and control 2012–2020** (WHO, 2012b); and
- The **Roll Back Malaria (RBM)** plan on action and investment to defeat malaria 2016–2030 (AIM), its multisectoral action plan (UNDP/RBM, 2013) and the housing and malaria consensus statement (RBM, 2015).

The world's population is growing rapidly, particularly in Africa and many countries with endemic vector-borne diseases. More than half of the world's population already lives in urban areas – i.e. more than 4 billion people. The trend of rapid urbanization observed in recent decades is predicted to continue and lead to a doubling in the number of city dwellers by 2050. A large part of future urbanization will take place in an unplanned way, leading to the expansion of slums and informal settlements. In 2016, there were 31 megacities (with more than 10 million inhabitants); this number is projected to rise to 41 by 2030. Most of these megacities are situated in the tropics or subtropics, in regions with one or more endemic vector-borne disease (UN-Habitat, 2016). This population growth, often coupled with substantial economic growth, drives the construction and modification of new and existing housing.

The critical importance of involving the housing sector

Our immediate surroundings – the way we plan and construct our cities, towns and houses – can be a powerful tool against diseases transmitted by vectors. Historically, improvements to housing and city planning have contributed to suppression or elimination of malaria and yellow fever even before targeted interventions or treatment became available. A large part of the success in eliminating malaria in high-income countries is probably due to mosquito-proofed housing and environmental management (Lindsay et al, 2002; Reiter et al, 2003). In the early 20th century, screening and improvements in housing helped bring about marked reductions in malaria across different settings (Keiser et al, 2005). One example is the significant reduction in malaria in the United States of America at the beginning of the 20th century, which many have attributed to improved housing (Boyd, 1926). A similar example is the construction of the Panama Canal, during which IVM was implemented as early as 1904, including the screening of living quarters and draining standing water, to reduce yellow fever and malaria (Le Prince et al, 1916).

Following the development of dichlorodiphenyltrichloroethane (DDT) in the 1940s, the global focus shifted to the concept of indoor residual house spraying with DDT as a "technological fix" for malaria, and this formed the backbone of the Global Malaria Eradication Programme of 1955–1979. As a result, other control measures, such as housing improvements, soon dropped out of use, leading to lessons from the past being neglected. However, housing improvement programmes for Chagas disease control have been successfully implemented in countries in Latin America since the 1940s, and implemented via multisectoral approaches – this has led to success in the elimination of domesticated vectors, and a reduction of transmission. Several initiatives in rural housing improvement in Central and South America have been implemented, and remain important elements in Chagas disease control (Dias et al, 2002; WHO, 2002; Briceno-Leon, 1987).

One of the objectives of IVM is to make rational use of resources **addressing, when possible, several vectors and diseases simultaneously,** where they occur together. Housing-related interventions, such as screening of windows, doors and eaves (areas where the roof meets or overhangs the walls), are ideal for this cost-effective and sustainable approach to disease reduction. This integrated approach is believed to be particularly beneficial for co-occurrence of malaria, leishmaniasis, dengue (and other arboviral diseases, such as yellow fever, chikungunya, Zika virus disease) and Chagas disease – provided the vectors are endophagic (Golding et al, 2015).

The push for the elimination of vector-borne diseases (especially malaria) and the prevention/mitigation of epidemics attracts significant resources. These are usually invested in highly efficient and immediate interventions such as insecticide-treated bed nets, indoor residual insecticide spraying and prompt and effective diagnosis and drug treatment. When target reductions in disease burden are achieved, these interventions are often scaled back notwithstanding available WHO guidance.[1] Housing improvements and other multisectoral interventions that modify the environment to prevent vector breeding have an important role in the sustainable **maintenance of successful elimination, epidemic mitigation and in preventing the (re-) introduction of vector-borne disease into disease-free areas**.

[1] Information note on the risks associated with the scale back of vector control in areas where transmission has been reduced (http://www.who.int/malaria/publications/atoz/scale-back-vector-control/en).

Funding for disease control programmes in health and other sector financing in general is usually limited and often insufficient. **Additional financial and organizational resources become available** when involving other sectors such as housing, urban planning and infrastructure. For little additional cost, new infrastructure and housing projects can be planned, designed and developed with vector control in mind, making urban settlements and cities intrinsically vector proof.

CLIMATE CHANGE, HOUSING AND VECTOR-BORNE DISEASES

Climate change is expected to influence vector range distribution, in particular for *Aedes aegypti* (Jansen & Beebe, 2010). Climate-related effects, **such as droughts or changes in precipitation patterns,** on the distribution of vectors and their diseases are to a large extent mediated by the nature of human environments. These environments – agriculture, rural settlements, cities – are important for climate change adaptation. Crude measures of adjustment, like storing water in open containers in dry periods or during periods of erratic water supply, can give rise to vector-borne diseases (Jansen & Beebe, 2010; Russell, 2009). Prioritizing the right adaptation interventions – such as house screening, installing a reliable water supply and reducing open water storage – can help to adapt to climate change by making housing, cities and human settlements vector proof. Traditional water storage practices, such as mud pots and drums, should be covered at all times to prevent mosquitoes breeding. Supplies of housing materials, such as storage tanks, roof gutters and water storage containers, need to be covered and taped in order to prevent mosquitoes breeding in them.

Figure 1 illustrates a logic model showing how multisectoral action can engender change to combat vector-borne diseases and in turn help achieve the objectives of the SDGs. The direct expected outcomes of the interventions are a reduction of disease endemicity and outbreaks according to the described pathway.

This reduction in morbidity and mortality can help reduce the burden and cost on health systems and curative services (SDG 3), increase school attendance (SDG 4) and increase the ability to work and contribute to society and economic growth (SDG 8). Multisectoral vector control programmes can also decrease inequality (SDG 10) when vulnerable populations (e.g. slum dwellers) profit from improved housing or improved public services (e.g. clean water). The reduction of health-care associated expenditures, driving people into poverty where no universal health coverage exists, protects from poverty (SDG 1). Investments in housing improvements can lead to economic growth and opportunities for decent work (SDG 8), make cities and communities safe, resilient and sustainable (SDG 11), and help adapt to climate change (SDG 13). A reliable piped water supply and rain and wastewater disposal offer clean water and sanitation (SDG 6), in turn reducing the disease burden of water-associated diseases such as diarrhoea (SDG 3). Furthermore, housing improvements, such as window screens, can lead to a reduction of household infestation of other pests and animals, leading to improved well-being.

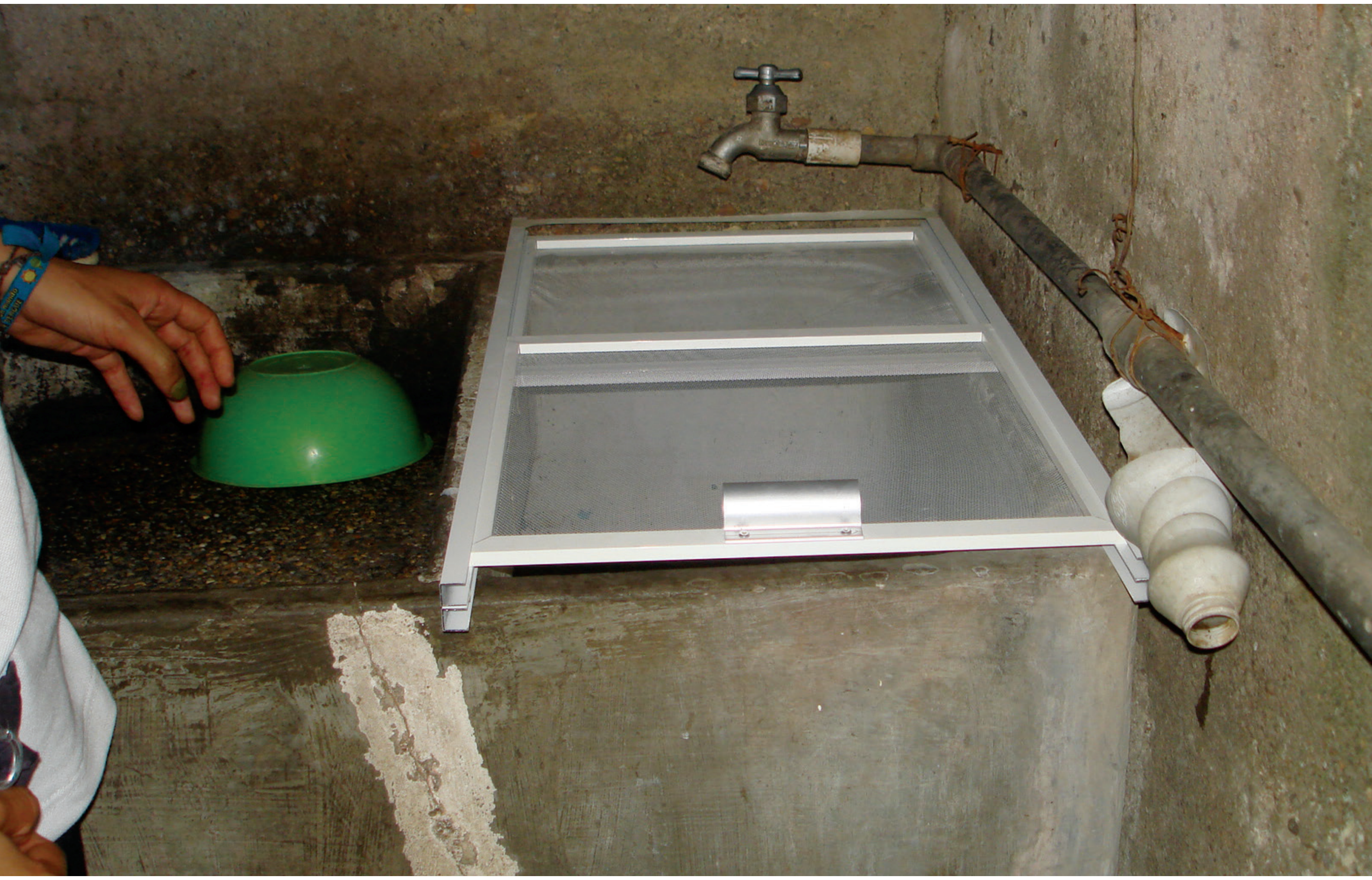


Figure 1. A logic model for achieving the goal of vector-resilient urban environments through multisectoral actions

Goal: Vector-resilient urban environments

Sectors	Interventions	Outputs	Short-term outcomes	Long-term outcomes	Objectives
	What are the main interventions?	What are the tangible outputs?	What will occur as a direct result of the interventions?	What results should follow from the initial outcomes?	What results should follow from the initial outcomes?
Housing Infrastructure Urban development Water Health Finance	Modification of housing Reliable water supply and drainage Sensible urban planning Waste disposal services Health services provision Vector control programmes Community involvement and education	Windows and doors fitted with screens/sealed houses Reduction of waste serving as vector breeding sources Reduction of stagnating water sources or water storage Well-designed toilets Reduction of urban heat islands Accessible and high-quality medical care Increased knowledge about vectors and diseases (Vocational) training to deliver interventions	Reduction of vector densities Reduction of vector-human contact (host biting rate) Reduction of infectious individuals in the community	Prevention of disease outbreaks Reduction of endemicity of vector-borne diseases Reduction of disease burden	SDG 3 Good health and well-being SDG 6 Clean water and sanitation SDG 8 Decent work and economic growth SDG 10 Reduced inequalities SDG 11 Sustainable cities and communities SDG 13 Climate action New Urban Agenda

Dengue, malaria, Chagas, leishmaniasis – links to housing and interventions to reduce disease burden

Vector-borne diseases connected to housing conditions

The transmission dynamics of arboviral diseases (e.g. dengue, chikungunya, Zika virus disease, yellow fever), malaria, Chagas disease, leishmaniasis and lymphatic filariasis all have direct links to the condition of housing and of peri-domestic environments.

The burden of vector-borne diseases

More than 80% of the world's population is at risk from at least one vector-borne disease and more than half at risk from two or more (WHO, 2017a; Golding et al, 2015). Table 1 gives an overview of the burden of morbidity and mortality of vector-borne diseases with housing-related transmission dynamics. In addition, vector-borne diseases impose a significant economic burden. This includes the costs of vector control, case management, reduced workforce, and less tourism in endemic areas (Shepard et al, 2016; Lee et al, 2017) and impeded economic growth (Gallup & Sachs, 2001).

Table 1. Estimated burden of selected vector-borne diseases attributable to the environment (including housing and the peri-domestic and community environment)

Disease	DALYs	Deaths	% of fraction (of DALYs) attributable to the environment
Malaria	23 074 450	258 702	42
Lymphatic filariasis	1 893 574	1	67
Dengue	1 369 867	27 249	95
Chagas disease	295 450	4 371	56
Leishmaniasis	903 053	12 952	27

Note: Estimates are based on a combination of comparative risk assessments, evidence synthesis, epidemiological calculations and expert evaluations. DALYs and deaths attributable to the environment are currently not available for chikungunya, Zika and yellow fever.
Source: Preventing disease through healthy environments (WHO, 2016a).

Key housing-related interventions

The principle of **"building the vector out"** is at the core of all housing interventions. The entry of disease-transmitting vectors into human habitation is prevented by screening windows, doors and eaves of houses, by fitting ceilings and by reducing vectors' indoor hiding and resting places, such as cracks and crevices in walls, floors and roofs. In addition, minimizing breeding sources around houses limits vector abundance. This is achieved by removing sources of stagnating water (e.g. gutters and drains) and open water storage containers. Key to this is a reliable supply of piped water, adequate sanitation facilities and services to safely manage faecal wastes. The appropriate choice of interventions depends on the local vector ecology and disease epidemiology.

Table 2. Housing-related interventions and vectors targeted

Interventions	Vectors targeted
Screening of windows, doors and eaves	*Aedes*, *Anopheles* and *Culex* mosquitoes, sandflies, some triatomine bugs
Reduction of aquatic habitats and breeding sources around houses (e.g. improvement of water supply and water storage, removing open gutters)	*Aedes*, some *Anopheles* species
Fitting of ceilings	*Anopheles*, *Aedes*, triatomine bugs
Reduction of cracks and crevices in walls, floors and roofs	Triatomine bugs, *Anopheles*, sandflies

Arboviral diseases

Dengue, chikungunya, Zika virus disease and **yellow fever** are arthropod-borne (arbo-) viral diseases. Currently, around 100 mosquito-transmitted viruses are known that can infect humans and carry the potential for future emerging epidemics. The most important vector of arboviral diseases is *Aedes aegypti* and to a lesser extent *Aedes albopictus*. The ability of the vector to exploit unconventional sites in which to lay eggs should not be underestimated. *Aedes aegypti* thrives in urban and semi-urban areas, which provide larval habitats such as water storage containers, open gutters, bottles, tyres and other discarded containers, plant pots and dishes, and broken or unsealed septic tanks. Open and unscreened housing, schools and workplaces allow the mosquito to access large urban populations leading to the establishment of stable transmission cycles and urban outbreaks of disease (LaDeau et al, 2015). Urban heat islands (areas in a city that are significantly warmer than their surroundings) are also considered to have an effect on vectoral capacity and thus disease transmission (Misslin et al, 2016; Araujo et al, 2015).

Interventions targeting *Aedes aegypti* (vector of dengue, chikungunya, yellow fever, Zika virus disease, lymphatic filariasis)	
Core non-housing interventions (WHO, 2009)	**Chemical control and biological control** • Larvicides (e.g. for drinking-water in storage containers) • Adulticides (e.g. indoor spraying, perifocal spraying) • Predatory fish • Predatory copepods • Insect repellents **Environmental manipulation (temporary) and changes to human behaviour** • Solid waste management • Street cleansing • Using mosquito nets while sleeping during daytime
Housing-related interventions	**Environmental modification (long-lasting) and changes to human habitation** • Improvement of water supply and water storage systems • Improvement in sanitation facilities and services • Mosquito-proofing of water storage containers • Management of essential containers (frequent emptying and cleaning), cleaning of gutters • Installing mosquito screening on windows, doors and other entry points (e.g. eaves) • Reducing open roof gutters
Additional considerations	• *Aedes* mosquitoes bite during the day. Therefore, achieving a minimum coverage threshold of screened buildings in a community might be necessary to achieve a protective effect for people at work, school or other places during the day. • Cost estimation: Installation of long-lasting insecticidal nets in houses in Acapulco, Mexico, cost US$ 25 per house annually in an interventional study in 2011–2013 (Che-Mendoza et al, 2015; Alfonso-Sierra et al, 2016). • House screening can be installed by homeowners while more complex interventions like a reliable piped water supply can be developed by local businesses and communities. Institutions of vocational training can teach the necessary skills to enable homeowners, craftspeople or local businesses to deliver the interventions. This helps reduce the costs of interventions, and involves and sensitizes the community while strengthening the local economy. • Potential adverse effects of screening houses (e.g. reduced indoor ventilation or reduced use of bed nets), acceptability and cost-benefit need to be considered during the planning phase of the interventions and should be evaluated when the programme has been implemented.

Malaria

Malaria parasites are transmitted by female mosquitoes of the genus *Anopheles*. Most *Anopheles* species bite between dusk and dawn – when humans are asleep in their houses (WHO, 2017c). The mosquitoes enter human dwellings through open windows, doors and eaves, attracted by human odour. Malaria is mainly a rural disease, yet it is also a significant problem in subtropical and tropical urban areas (Hay et al, 2005; Keiser et al, 2004). Urbanization and improved housing are regarded as important factors involved in the decline of malaria morbidity and mortality (Tusting et al, 2013; 2017). Urbanization leads to fewer vector breeding sites, less exposure to vectors by better housing and better access to health care. However, this progress has remained elusive for many of the close to a billion slum dwellers around the world as substandard housing and slums continue to be a risk factor for malaria transmission in endemic regions (Tusting et al, 2015).

Interventions targeting *Anopheles* (vector of malaria, lymphatic filariasis)	
Core non-housing interventions (WHO, 2016b; 2017b)	**Core vector control strategies** • Long-lasting insecticidal nets • Indoor residual spraying **Supplementary strategies** • Larval source management, including drainage and filling
Housing-related interventions	• Closing eaves • Installing ceilings • Screening doors and windows • Filling holes and cracks in walls and roofs/concrete walls
Additional considerations	• It is important to consider the effect of screening on indoor ventilation and thermal comfort. Sufficient ventilation is important for the uptake of bed net use, the acceptability of the intervention to inhabitants, and, in case of indoor use of solid fuels, the reduction of household air pollution linked with respiratory disease. • Estimation of costs: The cost of fully screening a house was US$ 11.11 per person in an interventional study in Gambia in 2006/2007 (Kirby et al, 2009). • The acceptability of window screening, ceilings and closed eaves is high among urban and rural residents alike, as shown in studies in the United Republic of Tanzania (Ogoma et al, 2009) and Gambia (Kirby et al, 2010). • Simple interventions, such as house screening, can be installed by homeowners, while more complex interventions can be implemented by local businesses and communities. Institutions of vocational training can teach the necessary skills to enable homeowners, craftspeople or local businesses to deliver the interventions. This helps to reduce the costs of interventions and involves, and sensitizes the community while strengthening the local economy. • Potential adverse effects of screening houses (e.g. reduced indoor ventilation or reduced use of bed nets), acceptability and cost-benefit need to be considered during the planning phase of the interventions and should be evaluated when the programme has been implemented.

Chagas disease

Chagas disease is caused by the protozoan parasite *Trypanosoma cruzi*, which is transmitted by triatomine bugs. It is endemic in large parts of Latin America (WHO, 2017d). The vector-borne transmission of Chagas disease is closely related to conditions of poverty, substandard housing and the nature of peri-domestic environments (Gürtler & Yadon, 2015; Coura, 2007). Most triatomines rest during the daytime in dark crevices (particularly in walls made of mud and mud brick) close to their blood source, and bite at night. Some find refuge in (palm-) thatched or mud and soil roofs, while some find suitable conditions to complete their life cycle within those houses. They also hide behind household items such as pictures, furniture, clothes, firewood, boxes etc. Furthermore, the peri-domicile environment (e.g. firewood, stones, discarded household items) offers important resting places from which house re-entry occurs. Animals around the house, such as chickens, cattle, goats and dogs, serve as reservoirs for the parasite. While Chagas disease has historically been a rural phenomenon, deforestation and encroachment have contributed to its urban and peri-urban presence (Dias et al, 2016). Housing improvements have been known as an important element in vector control since the first Chagas disease control activities in the 1940s (Dias et al, 2002). They are particularly important for sustainable control and the prevention of re-infestation of houses after insecticide spraying. The effectiveness of housing improvements depends on the main vector present (e.g. *T. dimidiata* and *R. prolixus*) (WHO, 2002).

Interventions targeting triatomine bugs (vector for Chagas disease)	
Core non-housing interventions	• Spraying of walls and roofs with insecticides (preferred method in areas where Chagas disease is endemic)
Housing-related interventions	**Reduction of vector resting places in human habitation**[1] • Plastering walls, and sealing cracks with clay/sand mixtures • Replacing thatched with corrugated zinc or iron roofs • Fitting of concrete/solid floors **Reduction of vector resting places in peri-domestic structures** • Improvement of peri-domestic structures housing animals, such as chicken coops and goat corrals, which are frequently infested, in a similar way to human habitation
Additional considerations	• It is important to improve a sufficient proportion of houses within a community to prevent re-infestation from non-targeted vector-infested houses and surroundings (Gürtler et al, 1992). • Cost estimation: Housing improvements against triatomine infestations cost between US$ 200–2000 per house in Venezuela in the 1980s (Briceno-Leon, 1987). • House improvements can be installed by local businesses and communities. Institutions of vocational training can teach the necessary skills to enable homeowners, craftspeople or local businesses to deliver the interventions. This helps to reduce the costs of interventions, and involves and sensitizes the community while strengthening the local economy.

Leishmaniasis

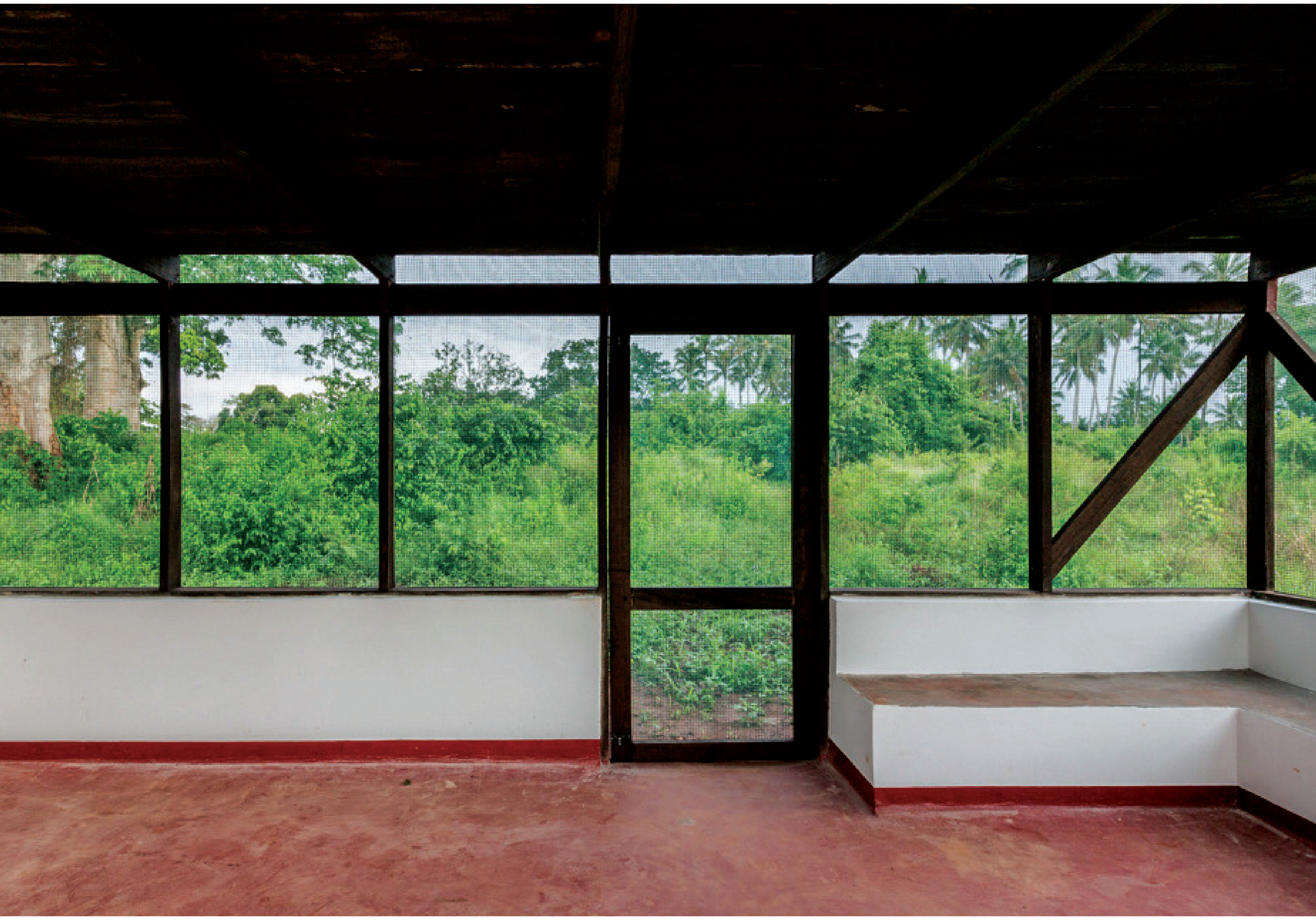
Leishmaniasis which occurs in visceral, cutaneous and mucocutaneous forms, is caused by the protozoan *Leishmania* parasites. The parasite is transmitted by female phlebotomine sandflies. The local epidemiology of leishmaniasis depends on the ecological characteristics of transmission sites. Conditions of poverty, substandard housing, poor sanitary conditions, an incursion of settlements into forests and a lack of waste management provide breeding sites and increase access to humans (WHO, 2017e). Leishmaniasis is usually found in rural settings but has also been implicated in urban outbreaks (Albuquerque et al, 2009; Carrillo et al, 2013).

Interventions targeting sandflies (vectors for leishmaniasis)	
Core non-housing interventions (WHO, 2016b)	• Indoor residual spraying (where vectors bite or rest indoors) • Long-lasting insecticidal nets or insecticide-treated curtains • Reservoir management (zoonotic and sylvatic cycles) • Environmental modification
Housing-related interventions	• House screening (where vectors bite or rest indoors)
Additional considerations	• The choice of vector control tools against leishmaniasis depends on the parasite, the vector and the transmission cycles (in particular, indoor versus outdoor biting of sandflies). A thorough understanding of the local situation is important to choose the right intervention strategies.

[1] Detailed instructions on how to improve housing to combat Chagas disease can be found in the WHO publication, Vector control: Methods for use by individuals and communities (1997) (Chapter 3 "triatomine bugs", pages 222–228).

Lymphatic filariasis

Lymphatic filariasis, also known as elephantiasis, is caused by filarial worms. Depending on the setting, they are transmitted by different mosquitoes: *Culex* across many urban and semi-urban areas, *Anopheles* in rural areas and *Aedes* on Pacific islands (WHO, 2017f). Therefore, there is not one general intervention since transmission dynamics and the appropriate interventions depend on the respective main vector. The interventions correspond to those for malaria (where *Anopheles* is the main vector) or arboviral diseases (where *Aedes* is the main vector). For *Culex*, house screening and sanitation facilities and services to safely manage faecal waste can be effective interventions.



From evidence to official recommendations – WHO's work on housing and vector-borne diseases

As demonstrated above, the distribution, transmission and impact of malaria, dengue, chikungunya, Chagas and other vector-borne diseases depend, to a substantial degree, on our human habitats. Therefore, housing improvements can be an effective and sustainable means of protection from these diseases, while yielding co-benefits beyond health outcomes and helping to mitigate the potential impact of climate change. The evidence base for the relationship between housing conditions and vector-borne diseases is growing. The housing sector has been recognized by the WHO and the Roll Back Malaria initiative as central to the multisectoral response required to reduce vector-borne diseases.

As a next step, evidence-based recommendations on housing and vector-borne diseases are needed. The WHO Department of Public Health, Environmental and Social Determinants of Health is currently developing housing and health guidelines covering a wide array of topics. These forthcoming guidelines will, in due course, be expanded to include a chapter specifically on housing and vector-borne diseases, which aims to provide official WHO recommendations, based on a systematic review of the available evidence, to actors in the housing sector. These recommended interventions can then be used as part of a toolbox of interventions for locally tailored approaches to vector control.

Key systematic reviews

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ISBN 978-92-4-151316-6