A global brief on vector-borne diseases

World Health Organization

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Foreword

World Health Day 2014 – Vector-borne diseases

With this World Health Day, WHO is drawing attention to a group of diseases that are spread by insects and other vectors, the heavy health and economic burdens they impose, and what needs to be done to reduce these burdens. Vector-borne diseases cause more than one million deaths each year. But death counts, though alarming, vastly underestimate the human misery and hardship caused by these diseases, as many people who survive infection are left permanently debilitated, disfigured, maimed, or blind.

As vectors thrive under conditions where housing is poor, water is unsafe, and environments are contaminated with filth, these diseases exact their heaviest toll on the poor – the people left behind by development. Measures that control the vectors, the agents of disease, provide an excellent, but underutilized opportunity to help these people catch up. This is one World Health Day message: countries and their development partners need to do much more to seize this opportunity.

Malaria, which is spread by mosquitoes, is the best-known and the biggest killer among vector-borne diseases, but there are others. Some, like dengue and yellow fever, tend to erupt in large outbreaks that can paralyze health systems and cause considerable economic and social disruption. Each year, around half a million patients with severe dengue require hospitalization.

Onchocerciasis causes blindness, chikungunya causes severe joint pain that can last for weeks, and Chagas disease in its late stage can cause heart failure and early death in young adults. Japanese encephalitis can permanently damage the central nervous system.

Schistosomiasis – the most widespread of all these diseases – contributes to poor nutritional status and poor school performance. Some forms of leishmaniasis are rapidly fatal; others cause severe facial disfigurement. Around 120 million people are currently infected with lymphatic filariasis, and about 40 million of them are disfigured and incapacitated by the disease.

Lost productivity is one consequence. Stigma and social exclusion are additional sources of misery, especially for women.

Many of these diseases have been historically confined to distinct geographical areas, but this situation has become more fluid due to a host of ills, including climate change, intensive farming, dams, irrigation, deforestation, population movements, rapid unplanned urbanization, and phenomenal increases in international travel and trade. These changes create opportunities for vectors and the diseases they spread to take up residence in new areas.

For all of these diseases, vector control is a powerful preventive tool that is not used to its full potential. The massive use of insecticides in the 1940s and 1950s successfully brought many important vector-borne diseases under control. Complacency set in. Control programmes were dismantled. Resources dwindled. Expertise was lost. And the diseases roared back with a vengeance – and a vanished infrastructure for their control.

In another worrisome trend, vectors in several countries are developing resistance to a highly effective class of insecticides that is also the most affordable.

We need to recreate the momentum for vector control and the fundamental capacities that underpin it, including staff with technical expertise, stronger surveillance systems, and better laboratory infrastructure. For vector-borne diseases, control programmes never tread water. They either surge ahead or sink. This is another key message for World Health Day: countries and their development partners must appreciate the urgent need to act before an alarming situation deteriorates any further.

A global health agenda that gives higher priority to vector control could save many lives and avert much suffering. Doing so is especially important for diseases like dengue and chikungunya, which have neither a vaccine nor an effective treatment. For diseases that can be prevented by a vaccine or effectively treated, vector control works as a complementary measure that can shrink the disease burden faster.

Taking action is entirely feasible. WHO promotes integrated vector management as the best approach to strengthen vector control. This approach uses a range of interventions, from indoor residual spraying to the use of natural insect predators, in combination and in a value-added way. Integrated management makes sense as many vector-borne diseases overlap geographically, some vectors cause several diseases, and some interventions provide protection against several vectors.

The control of vector-borne diseases can make a major contribution to poverty reduction, as it precisely targets the poor. It is my sincere wish that this World Health Day will invigorate vector control and give it the high profile it deserves. No one in the 21st century should die from the bite of a mosquito, a sandfly, a blackfly or a tick.

Dr Margaret Chan
Director-General, World Health Organization

Section 1: Vector-borne diseases: an overview

Vectors and the diseases that they can transmit

Vector	Diseases
Mosquitoes:	
Aedes aegypti	Dengue, yellow fever, chikungunya, Zika virus
Aedes albopictus	Chikungunya, dengue, West Nile virus
Culex quinquefasciatus	Lymphatic filariasis
Anopheles (more than 60 known species can transmit diseases)	Malaria, lymphatic filariasis (in Africa)
Haemagogus	Yellow fever
Sandflies	Leishmaniasis
Triatomine bugs	Chagas disease
Ticks	Crimean-Congo haemorrhagic fever, tick-borne encephalitis, typhus, Lyme disease
Fleas	Plague, Murine typhus
Flies (various species)	Human African trypanosomiasis, onchocerciasis

What are vectors?

Vectors are living organisms that can transmit infectious diseases between humans or from animals to humans.

Many of these vectors are bloodsucking insects that ingest disease-producing micro-organisms during a blood meal from an infected host (human or animal) and later inject them into a new host during their next blood meal. Mosquitoes are the best known disease vector. Others include certain species of ticks, flies, sandflies, fleas, bugs and freshwater snails (1).

An Ae. aegypti mosquito – the primary vector that spreads dengue, yellow fever and chikungunya
© Dr Francis Schaffner

More than half the world at risk

Vector-borne diseases are illnesses caused by pathogens and parasites in human populations. Every year more than one billion people are infected and more than one million people die from vector-borne diseases including malaria, dengue, schistosomiasis, leishmaniasis, Chagas disease, yellow fever, lymphatic filariasis and onchocerciasis.

One sixth of the illness and disability suffered worldwide is due to vector-borne diseases, with more than half the world's population currently estimated to be at risk of these diseases (2). The poorest segments of society and least-developed countries are most affected.

A child being tested for dengue at a hospital in Bangkok
© WHO/TDR

These diseases affect urban, peri-urban and rural communities but thrive predominantly among communities with poor living conditions – particularly lack of access to adequate housing, safe drinking water and sanitation. Malnourished people and those with weakened immunity are especially vulnerable.

These diseases also exacerbate poverty. Illness and disability prevent people from working and supporting themselves and their family, causing further hardship and impeding economic development. Dengue, for example, imposes a substantial economic burden on families and governments, both in medical costs and in working days lost due to illness. According to studies from eight countries, an average dengue episode represents 14.8 lost days for ambulatory patients at an average cost of US$ 514 and 18.9 days for non-fatal hospitalized patients at an average cost of US$ 1491 (3–7).

Vector-borne diseases therefore play a central role in poverty reduction and economic development. An econometric model for malaria suggests that countries with intensive malaria have income levels of only one third of those that do not have malaria (8).

Increasing threat

Back in the 1940s, the discovery of synthetic insecticides was a major breakthrough in the control of vector-borne diseases. Large-scale indoor spraying programmes during the 1950s and 1960s succeeded in bringing many of the major vector-borne diseases under control. By the late 1960s, many of these diseases – with the exception of malaria in Africa – were no longer considered to be of primary public health importance.

This triggered a major setback. Control programmes lapsed, resources dwindled, and specialists in vector control disappeared from public health units.

Within the past two decades, many important vector-borne diseases have re-emerged or spread to new parts of the world. Traditionally regarded as a problem for countries in tropical settings, vector-borne diseases pose an increasingly wider threat to global public health, both in terms of the number of people affected and their geographical spread.

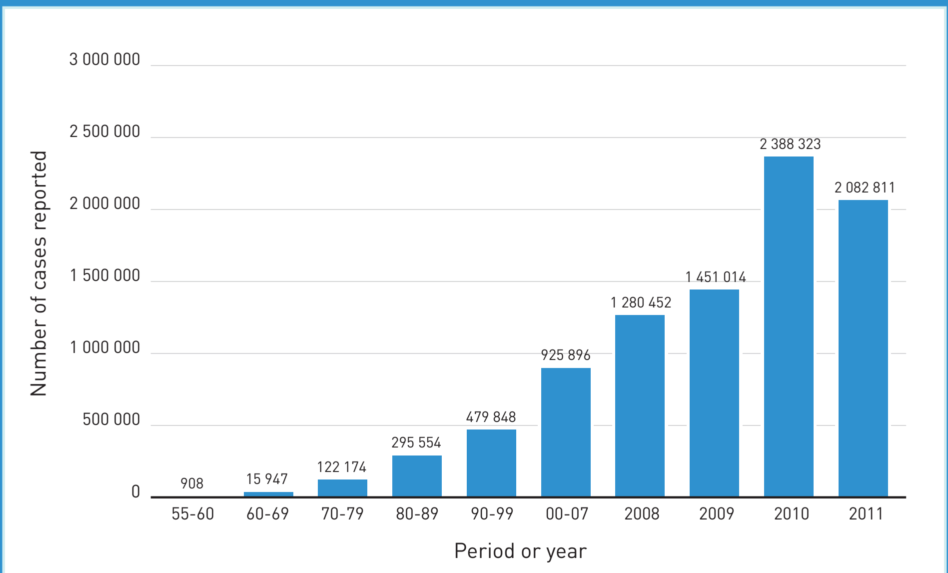
Their potential to spread globally, changes in climate, ecology, land-use patterns, and the rapid and increased movement of people and goods is threatening more than half the world's population.

Environmental changes are causing an increase in the number and spread of many vectors worldwide. Dengue in particular is emerging as a serious public health concern. In 2012, it ranked as the most important mosquito-borne viral disease with epidemic potential in the world. There has been a 30-fold increase in cases during the past 50 years, and its human and economic costs are staggering.

The primary vector for dengue, the *Aedes aegypti* mosquito, is now found in more than 20 European countries. This same mosquito species recently carried chikungunya to the Caribbean islands; the first cases of this debilitating disease seen in the Region of the Americas.

Alongside this alarming spread of vectors is the serious concern of increasing insecticide resistance. Today most species of vectors are showing resistance to many classes of insecticides. If existing insecticides lose their effectiveness this could erase all the gains made against malaria and other vector-borne diseases especially in parts of Africa.

And at the same time, the world is facing an extreme shortage of entomologists and vector-control experts. Very few African countries have entomology programmes at undergraduate university level and some countries have only a handful of expert entomologists.



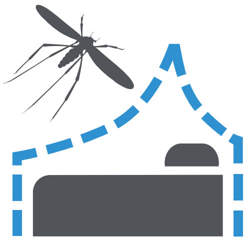
Average number of cases of dengue and severe dengue reported to WHO annually during 1955–2007 compared with the number of cases reported during 2008–2011 (9)

Renewed momentum

The world can no longer afford to be complacent. If we do not take action now, the implications are extremely serious for the entire globe.

For many vector-borne diseases, there are no vaccines, and drug resistance is an increasing threat. Vector control plays a vital role and is often the only way to prevent disease outbreaks.

Many existing interventions, such as insecticide-treated bednets and indoor spraying, are simple and proven. These vector-control tools can be particularly effective when used in combination with interventions such as mass drug administration involving large-scale treatment of affected communities.



Vector management programmes can also combine interventions and resources to target more than one disease – a component of an approach called integrated vector management.

For example, after intensive attempts to eradicate malaria in the 1950s and 1960s by indoor spraying with DDT (dichlorodiphenyl-trichloroethane), the prevalence of leishmaniasis fell dramatically in many countries and lymphatic filariasis disappeared in the Solomon Islands.

In many cases, increased funds and political commitment are needed to scale-up access to existing vector-control tools, as well as medicines and diagnostic tools.

At the same time, more investment in research is urgently needed to find improved solutions for fighting vectors and the diseases they transmit.

Combating these diseases calls for renewed momentum on a global scale; from global public health agencies, between countries and within regions, across government sectors, at all levels of government, and within communities and households.

Section 2: The diseases

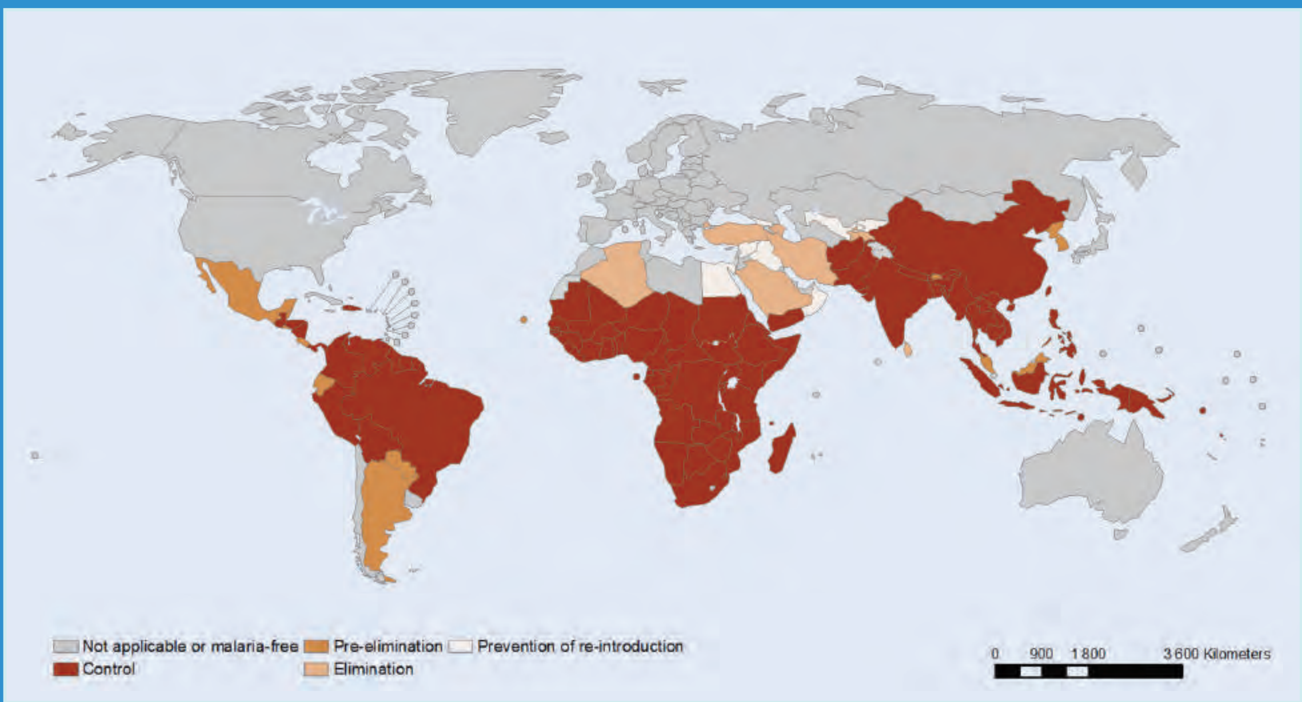
Malaria

Malaria is a parasitic disease that triggers fever, chills and a flu-like illness. Symptoms usually appear after a period of seven days or more after infection from a mosquito bite.

Early diagnosis and treatment of malaria is key. If left untreated, the disease can lead to severe illness and death. The best available treatment, particularly for *Plasmodium falciparum* malaria, is artemisinin-based combination therapy (ACT).

There is no commercially available vaccine against malaria although a promising vaccine against *P. falciparum* is currently being evaluated in a large clinical trial in seven African countries.

A child being treated for severe malaria in the United Republic of Tanzania



Countries with malaria transmission and phase of control programmes, December 2013

Source: World Health Organization

Burden

In 2012, there were about 207 million cases of malaria and an estimated 627 000 deaths (10). Increased prevention and control measures are dramatically reducing the malaria burden in many places. Since 2000, malaria mortality rates have fallen by 42% globally and by 49% in the WHO African Region.

Around the world, malaria transmission occurs in 97 countries, putting about 3.4 billion people at risk. The disease burden is heavily concentrated in sub-Saharan Africa, where an estimated 90% of malaria deaths occur. Four out of ten malaria-related deaths occur in the two highest burden countries: the Democratic Republic of the Congo and Nigeria.

> Populations most at risk are young children, pregnant women, people living with HIV, people affected by humanitarian emergencies and natural disasters, and non-immune travellers moving into endemic areas. The poorest of the poor in vulnerable communities, living in remote rural areas with limited access to health facilities, suffer the most.

Transmission

Malaria is caused by *Plasmodium* parasites transmitted through the bites of female *Anopheles* mosquitoes, which are active mainly between dusk and dawn.

Five parasite species cause malaria in humans and *Plasmodium falciparum and P. vivax* are the most common. *P. falciparum* is the most dangerous, with the highest rates of complications and mortality. This deadly form of malaria is a serious public health concern in most countries in sub-Saharan Africa.

Anopheline mosquitoes are the only vectors of the *Plasmodium* parasites. Each of the 60 known species of *Anopheles* that can transmit malaria has its own biological and ecological peculiarities. Disease transmission is more intense where the mosquito species has a long lifespan and a habit of biting only humans, for example *An. gambiae* and *An. funestus,* which are responsible for transmitting many of the deadly cases in Africa.

Malaria is caused by* Plasmodium *parasites transmitted through the bites of female* Anopheles *mosquitoes

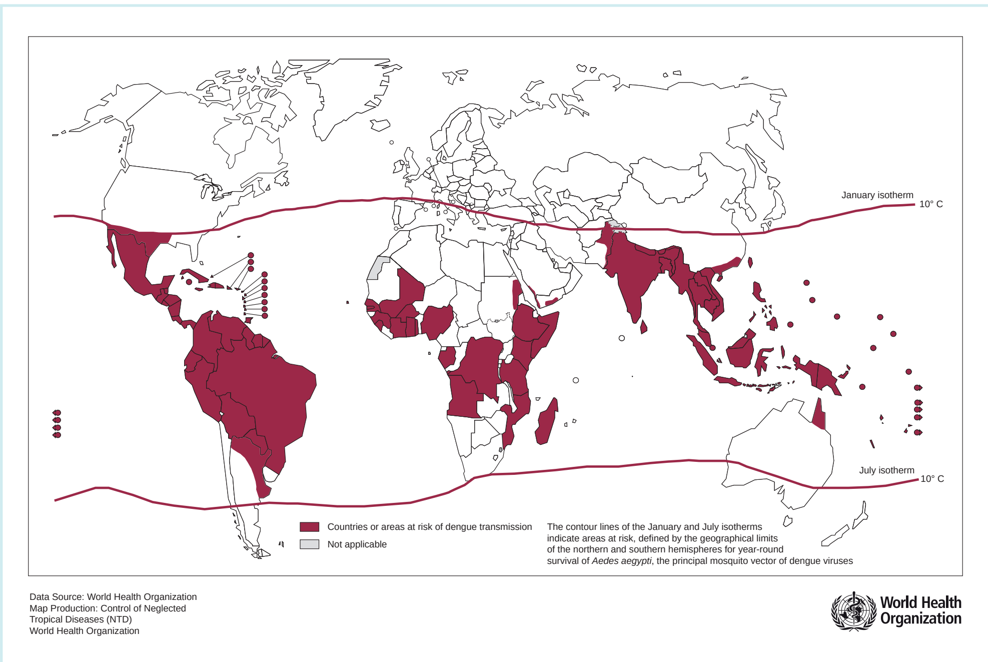
Dengue

Dengue fever is a severe, flu-like illness. Symptoms include high fever, severe headaches, muscle and joint pains, nausea, vomiting, swollen glands or rash. Dengue itself is rarely fatal, but severe dengue is a potentially fatal complication, with symptoms including low temperature, severe abdominal pains, rapid breathing, bleeding gums and blood in vomit.

Children being treated for dengue fever at the national paediatric hospital in Cambodia
© Erika Pineros

There are four known serotypes of dengue virus (DEN 1 to 4). Recovery from infection by one provides lifelong immunity against that particular serotype. However, subsequent infections by other serotypes increase the risk of developing severe dengue.

> No effective antiviral medications exist to treat dengue infection. In cases of severe dengue, it is critical to maintain the patient's body fluid volume.
>
> No commercial vaccine against dengue is available yet, although several candidate vaccines are currently in various phases of trials.



Countries or areas at risk of dengue transmission worldwide, 2012

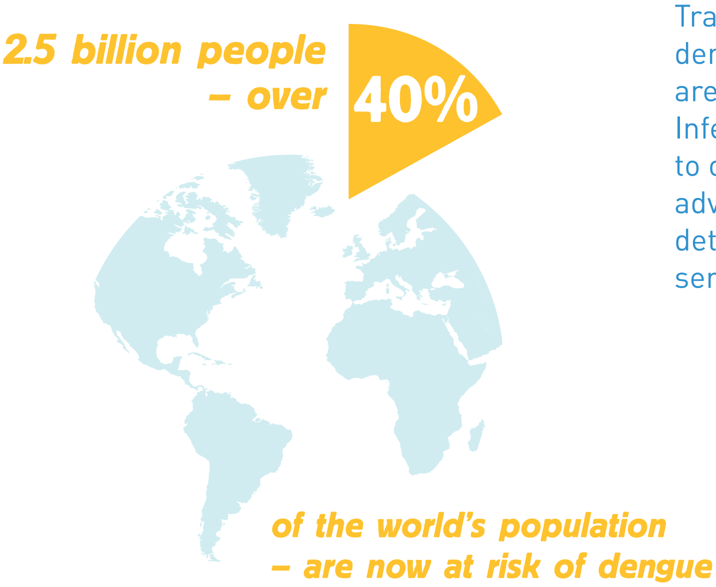
Burden

More than 2.5 billion people – over 40% of the world's population – are now at risk of dengue. WHO estimates there may be more than 100 million dengue infections worldwide every year. An estimated 500 000 people with severe dengue require hospitalization each year, a large proportion of whom are children. About 2.5% of those affected die.

Dengue is the most rapidly spreading mosquito-borne viral disease in the world. In the past 50 years, incidence has increased 30-fold with geographical expansion to new countries and, in the present decade, from urban to rural settings.

Before 1970, only nine countries had experienced severe dengue epidemics. The disease is now endemic in more than 100 countries in Africa, the Americas, the Eastern Mediterranean, South-East Asia and the Western Pacific. The Americas, South-East Asia and the Western Pacific Regions are the most seriously affected, with more than 2.3 million cases reported in 2010.

Not only is the number of cases increasing as the disease spreads to new areas, but more serious outbreaks are occurring. The threat of a possible outbreak of dengue fever now exists in Europe, with local transmission of dengue reported for the first time in Croatia and France in 2010 and an important outbreak on the Madeira Islands of Portugal in 2012. Cases were also reported in Florida (United States of America) and Yunnan province of China in 2013.



Transmission

The *Aedes aegypti* mosquito is the primary vector of dengue. The virus is transmitted to humans through the bites of infected female mosquitoes. Once an infected mosquito has incubated the virus for 4–10 days, it can transmit the virus for the rest of its life.

Infected humans are the main carriers and multipliers of the virus, serving as a source of the virus for uninfected mosquitoes. Patients who are already infected with the dengue virus can transmit the infection (for 4–5 days; maximum 12) via *Aedes* mosquitoes once their first symptoms appear.

The *Ae. aegypti* mosquito lives in urban habitats and breeds mostly in man-made containers. This species is a daytime feeder; its peak biting periods are early in the morning and in the evening before dusk. Female *Ae. aegypti* bite multiple people during each feeding period.

Aedes albopictus, a secondary dengue vector in Asia, has spread to North America and Europe largely due to the international trade in used tyres (a breeding habitat), timber and other goods such as 'lucky bamboo' (a decorative house plant that is marketed worldwide). This mosquito species can survive in cooler temperate regions of Europe. *Ae. albopictus* has a wide geographical distribution, is particularly resilient, and can survive in both rural and urban environments. The mosquito's eggs are highly resistant and can remain viable throughout the dry season. It is also a daytime feeder.

Travellers play an essential role in the spread of dengue, as they can carry new dengue strains into areas where mosquitoes can transmit infection. Infections in travellers can provide early alerts to outbreaks, particularly if they have access to advanced research facilities that can provide detailed information about a virus, such as serotype and sequencing.

Chikungunya

Symptoms of chikungunya are fever and severe joint pain that can last for weeks. Other symptoms include muscle pain, headache, nausea, fatigue and rash.

Most patients recover fully, but in some cases joint pain may persist for several months, or even years. Occasional cases of eye, neurological and heart complications have been reported, as well as gastrointestinal complaints. Serious complications are not common but, in older people, the disease can contribute to the cause of death. Often symptoms are mild and the infection may go unrecognized, or be misdiagnosed in areas where dengue occurs.

The disease typically consists of an acute illness with fever, skin rash and incapacitating joint pains that could last for several months. Chikungunya shares the same vectors, symptoms and geographical distribution as dengue, except for the presence of joint pains.

There is no specific treatment for chikungunya. Symptomatic or supportive treatment basically comprises rest and use of acetaminophen or paracetamol to relieve fever and a non-steroidal anti-inflammatory agent to relieve joint pain.

Burden

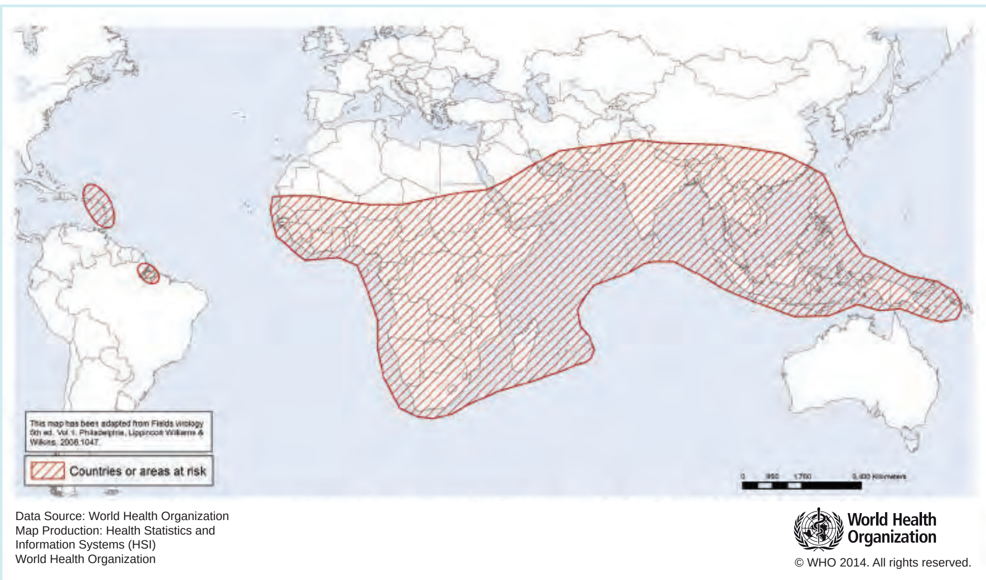
Chikungunya occurs in Africa, Asia and the Indian subcontinent. In recent decades, there have been outbreaks of the disease in countries that have never recorded cases before.

In 2005–2006, an outbreak in Réunion Island (a French territory in the Indian Ocean) affected around one-third of the population (266 000 of 775 000 inhabitants). The outbreak spread to several countries in the WHO South-East Asia Region, including India, where 1 400 000 cases were reported during 2006. In 2007, disease transmission was reported for the first time in Europe in a localized outbreak in north-eastern Italy.

In December 2013, the first cases of local transmission of chikungunya were detected in the WHO Region of the Americas, in the Caribbean island of Saint Martin. The disease has since been reported in other islands in the Region.

Transmission

In Asia and the Indian Ocean region, the main vectors of chikungunya are *Aedes albopictus* and *Ae. aegypti*. In Africa, a larger range of *Aedes* species transmit the virus as well as *Culex annulirostris, Mansonia uniformis* and *Anopheles* species.



WHO Map from International Travel and Health showing chikungunya, countries or areas at risk (11)

Yellow fever

Yellow fever, the original viral haemorrhagic fever, was one of the most feared lethal diseases before the development of an effective vaccine.

The first symptoms of the disease usually appear 3–6 days after infection. The first, or 'acute', phase is characterized by fever, muscle pain, headache, shivers, loss of appetite, nausea and vomiting. After 3–4 days, most patients improve and symptoms disappear. However, 15% of patients enter a 'toxic' phase: fever returns and the patient develops jaundice and sometimes bleeding, with blood appearing in the vomit.

There is no specific treatment for yellow fever. Supportive care needed to treat dehydration, respiratory failure, fever and associated infections is not easily available to many yellow fever patients. About 50% of patients who enter the toxic phase die within 10–14 days.

Vaccination is the most important preventive measure against yellow fever. A single dose of the vaccine provides life-long immunity.

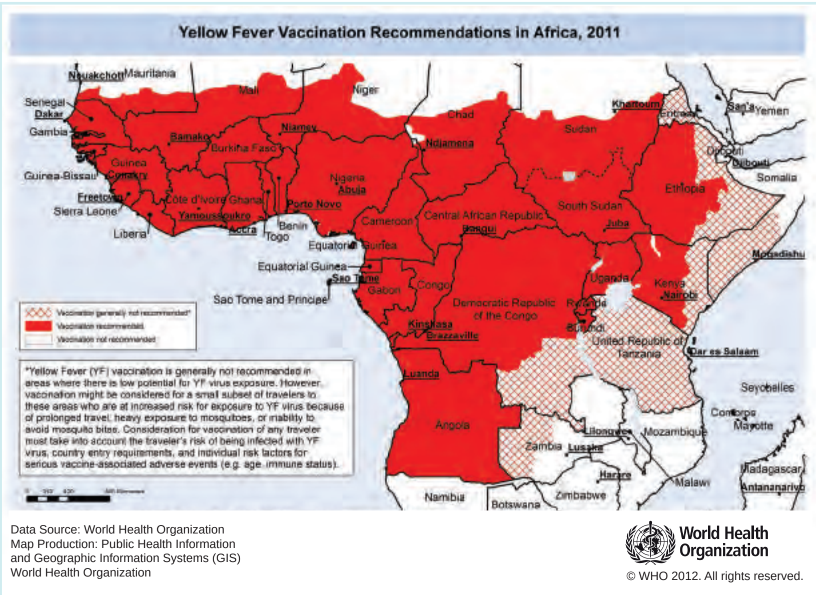
Burden

Every year there are around 200 000 cases of illness and 30 000 deaths from yellow fever. The number of yellow fever cases has increased over the past two decades due to declining population immunity to infection, deforestation, urbanization, population movements and climate change.

Transmission

Yellow fever is transmitted by the *Haemagogus* and *Aedes* species of mosquitoes between monkeys and humans. Outbreaks have occurred in recent years in seasonal workers, nomadic and displaced people in several African countries.

In the past 30 years, dramatic increases in the distribution of the urban mosquito vector, *Ae. aegypti*, as well as the rise in air travel, have increased the risk of introduction and spread of yellow fever to North and Central America, the Caribbean and Asia.



WHO Maps from International Travel and Health showing areas at risk (11)

Japanese encephalitis

Japanese encephalitis virus is transmitted to humans through infected *Culex* mosquitoes.

Most human infections are asymptomatic or result in only mild symptoms; however, a small percentage of infected people develop inflammation of the brain (encephalitis), with symptoms including sudden onset of headache, high fever, disorientation, coma, tremors and convulsions. One quarter of severe cases can be fatal, and 30% of those who survive severe infection have lasting central nervous system damage.

There is no specific treatment for the disease; supportive care and management of complications can provide some relief.

The vaccine against Japanese encephalitis is the single most effective preventive measure against this disease.

Burden

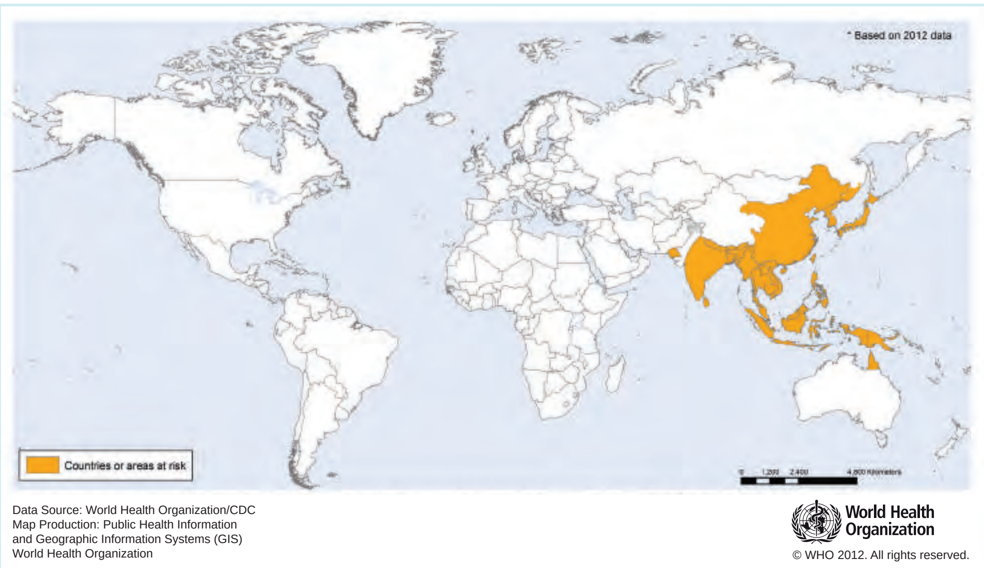
Japanese encephalitis causes an estimated 50 000 cases and 10 000 deaths every year, mostly of children aged less than five. It occurs across Asia, from the islands of the Western Pacific in the east to the Pakistani border in the west, and from the Republic of Korea in the north to Papua New Guinea in the south.

While cases have been reduced considerably in Japan, the Republic of Korea, and Taiwan, China, the disease has expanded to India, Nepal and Sri Lanka where it has become a substantial public-health problem.

Transmission

Transmission of the Japanese encephalitis virus occurs primarily in rural agricultural areas, particularly around flooded rice fields, but can also occur near urban centres. In temperate areas of Asia, transmission of the virus is seasonal.

The virus is transmitted between mosquitoes, in particular *Culex tritaeniorhynchus*, and animals such as pigs and wading birds. Humans are incidental or 'dead-end' hosts, because they usually do not develop high enough concentrations of the virus in their bloodstreams to infect feeding mosquitoes.



WHO Map from International Travel and Health showing Japanese encephalitis countries or areas at risk (11)

Lymphatic filariasis

Infection with lymphatic filariasis, commonly known as elephantiasis, occurs when thread-like, filarial parasites are transmitted to humans through mosquitoes.

A patient with lymphatic filariasis with lymphoedema, Orissa, India
© Sean Hawkey

Microscopic parasitic worms lodge in the lymphatic system and disrupt the immune system. They live for 6–8 years and, during their lifetime, produce millions of microfilariae (tiny larvae) that circulate in the blood.

The majority of infections have no symptoms but silently cause damage to the lymphatic system and the kidneys as well as alter the body's immune system.

Acute episodes of local inflammation involving skin, lymph nodes and lymphatic vessels often accompany chronic lymphoedema (tissue swelling).

Infection usually occurs in childhood, but the worst symptoms of chronic disease generally appear later in life in adults – in men more often than in women – and include damage to the lymphatic system, arms, legs or genitals, which causes significant pain, loss of productivity and social exclusion.

Recommended treatment to clear the parasites from the bloodstream is a single dose of albendazole given together with either diethylcarbamazine or ivermectin. Interruption of transmission of infection can be achieved if at least 65% of the population at risk is treated for at least 5 years.

Severe lymphoedema and acute inflammation can be improved with strict hygiene, skin care, exercise and elevation of affected limbs. Hydrocele (fluid accumulation) can be cured with surgery.

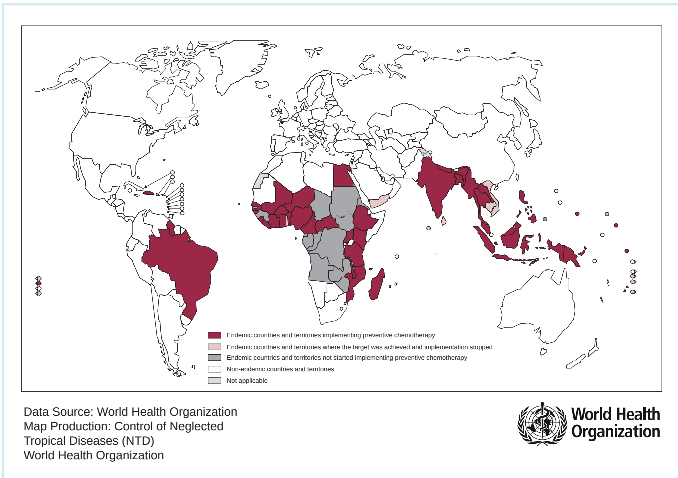
Burden

More than 120 million people are currently infected with lymphatic filariasis, about 40 million of whom are disfigured and incapacitated by the disease.

Lymphatic filariasis afflicts more than 25 million men with genital disease and more than 15 million people with lymphoedema. Approximately 65% of those infected live in the South-East Asia Region, 30% in the African Region, and the remainder in other tropical areas.

Transmission

Lymphatic filariasis is transmitted by different types of mosquitoes, for example by the *Culex* mosquito, widespread across urban and semi-urban areas; *Anopheles* mainly in rural areas; and *Aedes*, mainly in the Pacific Islands and parts of the Philippines; and by three types of parasite. (*Wuchereria bancrofti* - responsible for 90% of cases, *Brugia malayi and B. timori*).



Distribution and status of preventive chemotherapy for lymphatic filariasis worldwide, 2012

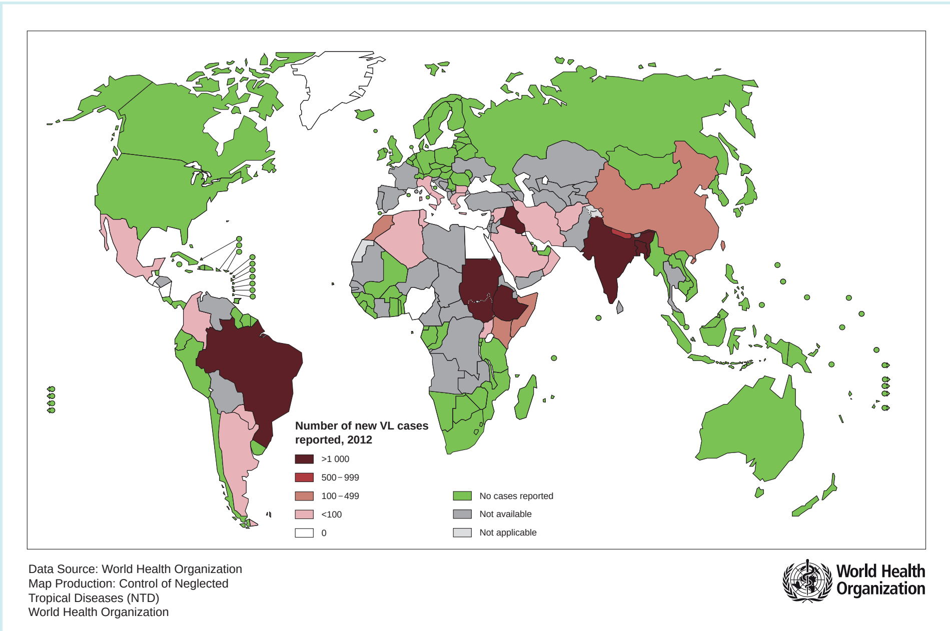
The Leishmaniases

There are three main types of leishmaniasis – visceral (often known as kala-azar and the most serious form of the disease), cutaneous (the most common) and mucocutaneous.

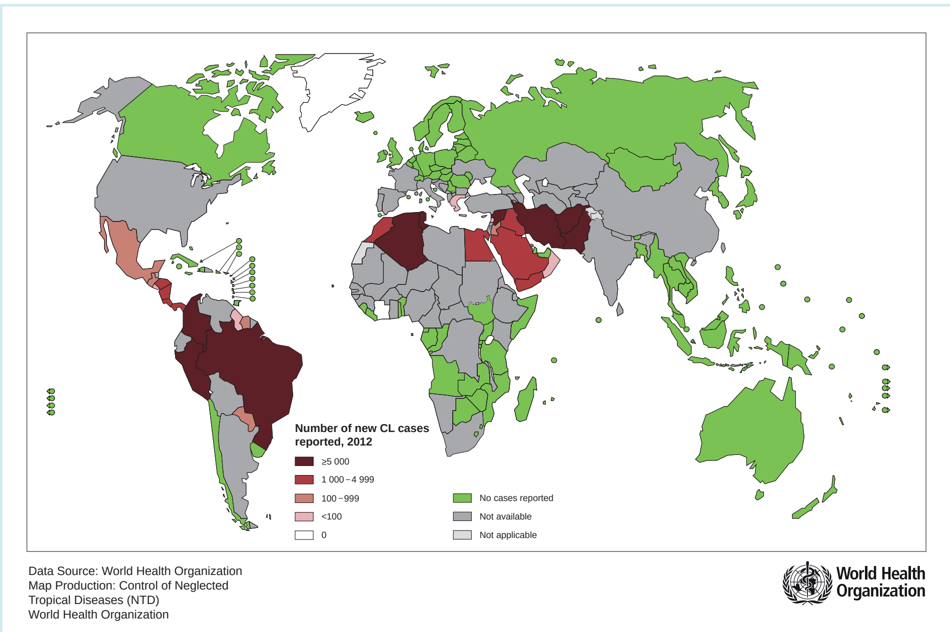
Depending on the type of leishmaniasis, the disease can cause fever, weight loss, enlargement of the spleen and liver, anaemia, rash and skin ulcers. Both cutaneous and mucocutaneous leishmaniasis can lead to disfiguring scars and associated stigma.

Early diagnosis and treatment with various medications reduces the spread of the disease and can prevent disabilities and death.

Patient awaiting treatment for visceral leishmaniasis during an outbreak in Libo Kemkem, Ethiopia



Status of endemicity of visceral leishmaniasis (VL), worldwide, 2012



Status of endemicity of cutaneous leishmaniasis (CL), worldwide, 2012

Burden

There are an estimated 1.3 million new cases of leishmaniasis and 20 000 to 30 000 deaths from it every year. An estimated 300 000 of these cases are of the visceral form and most of these occur in Bangladesh, Brazil, Ethiopia, India, South Sudan and Sudan. About 95% of cutaneous leishmaniasis cases occur in the Americas, the Mediterranean basin, and the Middle East and Central Asia. Over two-thirds of new cutaneous leishmaniasis cases occur in six countries: Afghanistan, Algeria, Brazil, Colombia, Iran (Islamic Republic of) and the Syrian Arab Republic and mucocutaneous leishmaniasis occurs mainly in the Region of the Americas (Bolivia, Brazil and Peru).

Transmission

Leishmaniasis is caused by the *Leishmania* parasite transmitted by the phlebotomine species of sandfly, which is found throughout the tropical and temperate regions of the world. Female sandflies become infected with the *Leishmania* parasites when they suck blood from an infected person or animal.

Sandflies live in relatively cool and humid areas such as the interior of houses, latrines, cellars, caves, cracks in walls, household rubbish, dense vegetation, tree holes, animal burrows and termite hills. Leishmaniasis occurs mainly in rural and peri-urban areas where *Leishmania* parasites are carried by humans, dogs and other animals.

The disease affects mainly the poorest people in the community, and is associated with population displacement, poor housing and lack of resources. During the past 20 years, the disease has spread considerably due to migration and environmental changes such as deforestation, building of dams, irrigation schemes, urbanization and population displacement due to conflicts and war.

Malnutrition, poor living conditions and sleeping outside or on the ground increase the risk of becoming infected. Poverty can also increase the progression of the disease, worsening illness and leading to death, mainly through poor nutrition and weak immunity.

Onchocerciasis (river blindness)

Onchocerciasis is a parasitic disease that causes intense itching and depigmentation of the skin ('leopard skin'), lymphadenitis resulting in hanging groins and elephantiasis of the genitals, serious visual impairment, and blindness.

Symptoms usually begin to show 1–3 years after infection. Treatment is with ivermectin, which kills the microfilariae (baby worms) and relieves skin itching caused by the disease.

Burden

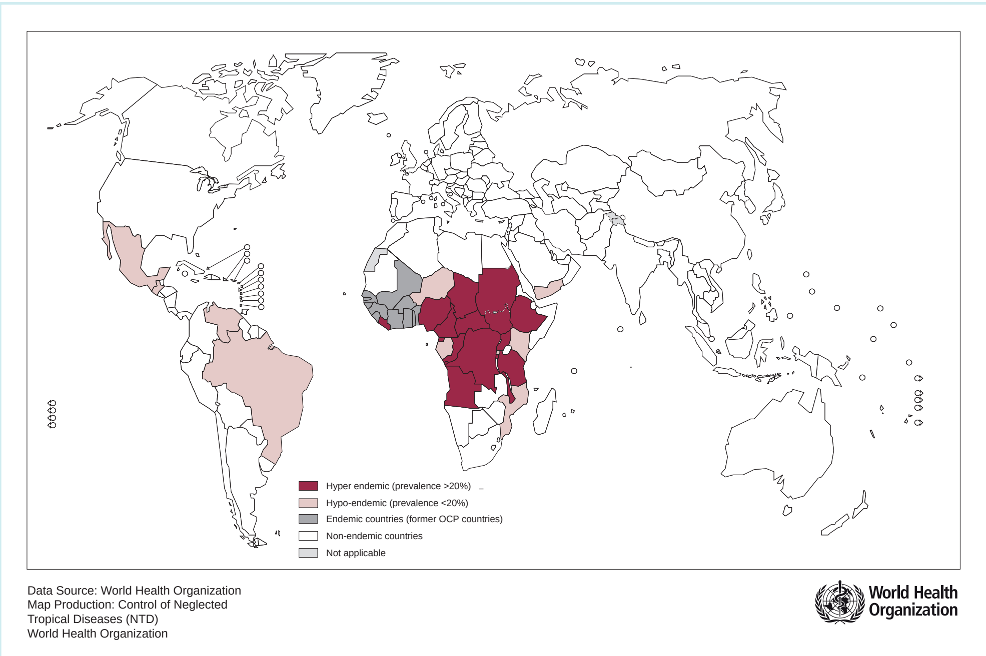
Onchocerciasis is the world's second leading infectious cause of blindness, after trachoma. A total of 37 million people are infected worldwide.

The disease occurs in 31 countries in Africa as well as in Guatemala, southern Mexico, some areas in the Bolivarian Republic of Venezuela, small areas of Brazil. Colombia is the first country to have eliminated the disease in 2013 and may be followed by Ecuador in 2014. Yemen is the only endemic country in the Arabian peninsula.

Transmission

Onchocerciasis is caused by a parasitic worm, *Onchocerca volvulus*, that can live for up to 14 years in the human body. The disease is transmitted between humans through the bite of a blackfly (*Simulium*).

The blackfly lays its eggs in the water of fast-flowing rivers where they mature into adult blackflies in 8 to 12 days. The female blackfly typically seeks a blood meal after mating and, upon biting a person who is infected with onchocerciasis, may ingest worm larvae, which can then be passed on to the next person bitten by the blackfly. Eventually, the transmitted worm larvae develop into adult worms that can be more than 50 cm in length. They settle into fibrous nodules in the human body close to the surface of the skin or near the joints and, when they die, cause a variety of conditions including skin lesions, intense itching and blindness.



Distribution of onchocerciasis, worldwide, 2013

Crimean–Congo haemorrhagic fever

Crimean-Congo haemorrhagic fever is a severe viral disease. The onset of symptoms is sudden. They include fever, muscle ache, dizziness, neck pain and stiffness, backache, headache, sore eyes and sensitivity to light. There may be nausea, vomiting, diarrhoea, abdominal pain and sore throat early on, followed by sharp mood swings and confusion. Other signs include fast heart rate, a rash, enlarged lymph nodes and liver and kidney failure.

More than one third of people infected die within the second week of illness.

The main approach to managing Crimean-Congo haemorrhagic fever is to treat symptoms. The antiviral drug ribavirin has been shown to be effective.

There is currently no safe and effective vaccine widely available for human use.

Burden

The disease is endemic in Africa, the Balkans, the Middle East and Asia. Outbreaks have the potential to become epidemics and up to 40% of people infected die from the disease.

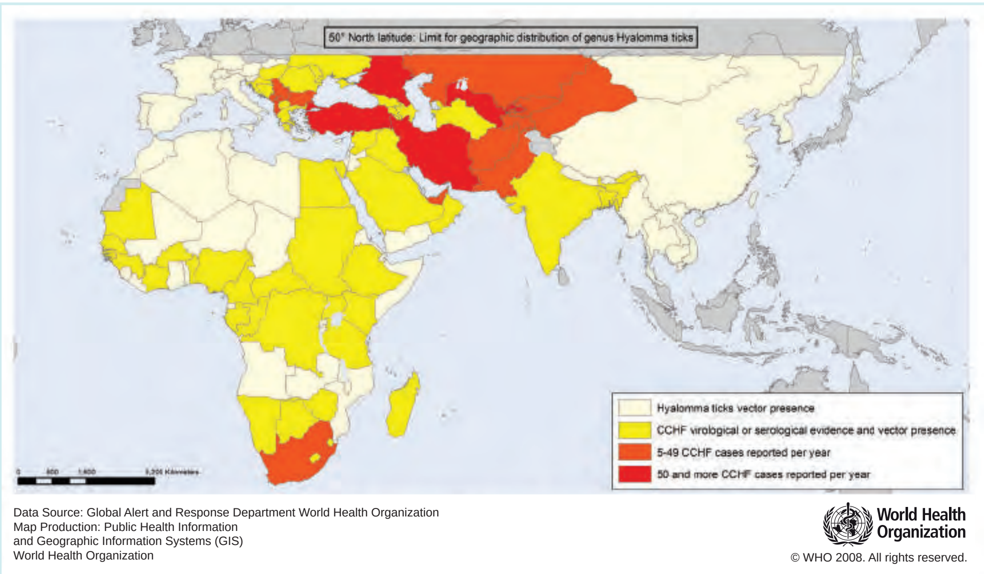
Transmission

Crimean-Congo haemorrhagic fever is a disease caused by a tick-borne virus (*Nairovirus*) of the *Bunyaviridae* family.

Although several types of tick can become infected with Crimean-Congo haemorrhagic fever virus, ticks of the genus *Hyalomma* are the principal vector. The hosts of the virus include wild and domestic animals such as cattle, sheep, goats and ostriches.

The virus is transmitted to humans either by tick bites or through contact with the blood or tissues of an infected animal during and immediately after slaughter, putting workers of the livestock industry and agricultural workers at risk.

Human-to-human transmission can occur through close contact with the blood, secretions, organs or other bodily fluids of infected people. Hospital-acquired infections can also occur due to improper sterilization of medical equipment, reuse of needles and contamination of medical supplies.



Geographical distribution of Crimean-Congo haemorrhagic fever, 2008

Lyme disease

Lyme disease symptoms include fever, chills, headache, fatigue, and muscle and joint pain. A rash often appears at the site of the tick bite and gradually expands to a ring with a central clear zone, before spreading to other parts of the body.

If left untreated, infection can spread to joints, the heart and central nervous system. Arthritis may develop up to 2 years after onset.

Most cases of Lyme disease can be treated successfully with a course of antibiotics.

Burden

Lyme disease occurs in rural areas of Asia, north-western, central and eastern Europe and the United States of America (USA).

The first recognized outbreak of this disease occurred in Connecticut, USA, in 1975. The current burden is estimated at 7.9 cases per 100 000 people in the USA, according to the United States Centers for Disease Control and Prevention (12).

Since the mid-1980s, the disease has been reported in several European countries. It is now the most common tick-borne disease in the Northern Hemisphere.

Transmission

Lyme disease (Lyme Borreliosis) is caused by *Borrelia* bacteria and is transmitted through the bite of infected deer ticks (*Ixodes* species). Many species of mammals can be infected and rodents and deer act as important reservoirs.

People living in or visiting rural areas, particularly campers and hikers, are most at risk. If bitten, the tick should be removed as soon as possible.

Ixodes ricinus tick
© ECDC / G Hendrick

Tick-borne encephalitis

Infection with tick-borne encephalitis causes influenza-like symptoms, high fever, severe headache, nausea, vomiting and back pain. In about 30% of cases, the illness progresses to affect the central nervous system and may result in paralysis or death. The illness is more severe in older people.

There is no specific treatment. Anti-inflammatory medicines can be used to relieve symptoms. Some people may need intubation and ventilatory support.

Vaccination is recommended for people living, or planning to hike or camp in a high-risk area.

Burden

There are three types of tick-borne encephalitis: European (also known as Western), Far Eastern and Siberian.

The Russian Federation particularly western Siberia have the most cases in the world. Other countries that have reported cases, or that have high prevalence of the virus in ticks, include Albania, Austria, Belarus, Bosnia, Bulgaria, China, Croatia, Denmark, Finland, Germany, Greece, Hungary, Italy, Mongolia, Norway, Poland, the Republic of Korea, Romania, Serbia, Slovakia, Slovenia, Sweden, Switzerland, Turkey and Ukraine. In the past 20 years, an average of 8500 cases were reported from 19 European countries.

Transmission

The disease is transmitted through the bite of infected ticks (*Ixodes* species) or, more rarely, by consuming unpasteurized dairy products from infected goats, sheep or cows. Most cases occur in the warmer months from April to November. The virus has been found at altitudes up to 1500 m (13).

Other tick-borne diseases

Other diseases caused by ticks include tick-borne relapsing fever, rickettsial fevers, Q fever, tularaemia and Kyasanur forest disease.

Some of these diseases are quite localized so governments need to tailor control and treatment interventions according to the local disease burden.

Ticks also carry diseases that infect domestic animals and can cause great economic loss to livestock farmers.

Treatment for some of the major tick-borne diseases

Disease	*Treatment*
Tick-borne relapsing fever	Tetracycline antibiotic or derivatives
Tick-borne rickettsial fevers	Tetracycline antibiotic or chloramphenicol can be used
Lyme disease	Tetracycline antibiotic or derivatives Children can be treated with penicillin
Tularaemia	Streptomycin antibiotic
Tick-borne viral encephalitis	No specific treatment

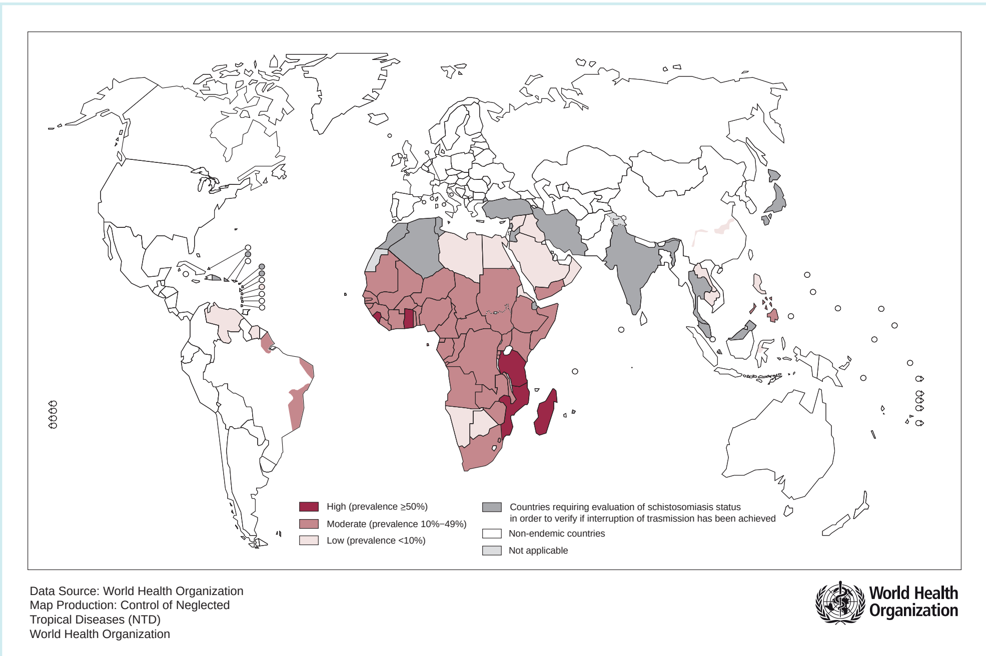
Schistosomiasis (bilharzia)

Schistosomiasis is a chronic disease. Intestinal schistosomiasis can cause abdominal pain, diarrhoea, blood in the stool, liver and spleen enlargement, fluid in the peritoneal cavity and hypertension of the abdominal blood vessels.

Urogenital schistosomiasis causes blood in the urine, lesions and fibrosis of the bladder, ureter and genitals, kidney damage and sometimes bladder cancer. It can cause infertility and increases the risk of HIV infection in women (14).

Children indicate that they have seen blood in their urine – a sign of schistosomiasis – during an education session at a primary school in Bongo, Ghana
© M Wilson

In children, it can cause anaemia, stunting and a reduced ability to learn, although the effects are usually reversible with treatment.



Distribution of schistosomiasis, worldwide, 2012

Burden

More than 700 million people live in areas where they are at risk of infection. Schistosomiasis has been documented in 78 countries, and is highly prevalent in 52 countries, most of which are in sub-Saharan Africa. At least 249 million people required treatment for schistosomiasis in 2012.

Several million people all over the world suffer from severe chronic illness due to schistosomiasis.

Typical transmission sites for schistosomiasis (a) drainage canal, (b) river bank, (c) irrigated rice fields and (d) banks of natural and artificial lakes (15)
© J Rozendaal

Transmission

Schistosomiasis is caused by blood flukes (trematode worms). People become infected when larval forms of the parasite – released by freshwater snails – penetrate the skin during contact with infested water.

Four types of freshwater snails – *Biomphalaria, Bulinus, Oncomelania* and *Neotricula* – are vectors of the *schistosoma* parasite.

These snails live in fresh water, ranging from small temporary ponds and streams to large lakes and rivers. They are most common in shallow waters where water plants are abundant and in water moderately polluted with organic matter, such as sewage, as is often the case near human dwellings.

Biomphalaria and *Bulinus snails* are hermaphrodites so one individual snail can recolonize an entire body of water.

People become infected when they come into contact with larvae of the parasite in fresh water. The larvae penetrate the skin and are carried to the liver where they develop into adult schistosomes. Adult worms live in blood vessels where the females lay eggs.

Symptoms of schistosomiasis are caused by the body's reaction to the worms' eggs, not by the worms themselves. Some of the eggs are passed out of the body in the faeces or urine where they continue the parasite life-cycle if they reach freshwater sources. Most parasite eggs are trapped in body tissues, causing immune reactions and progressive damage to organs.

People acquire schistosomiasis through repeated contact with fresh water during collection of water, laundry, bathing, fishing, farming, swimming and recreational activities. Communities without access to safe drinking water and sanitation are at greatest risk of infection. Careful planning is required to ensure that water resource development schemes – particularly irrigation schemes – do not contribute to the introduction and spread of schistosomiasis.

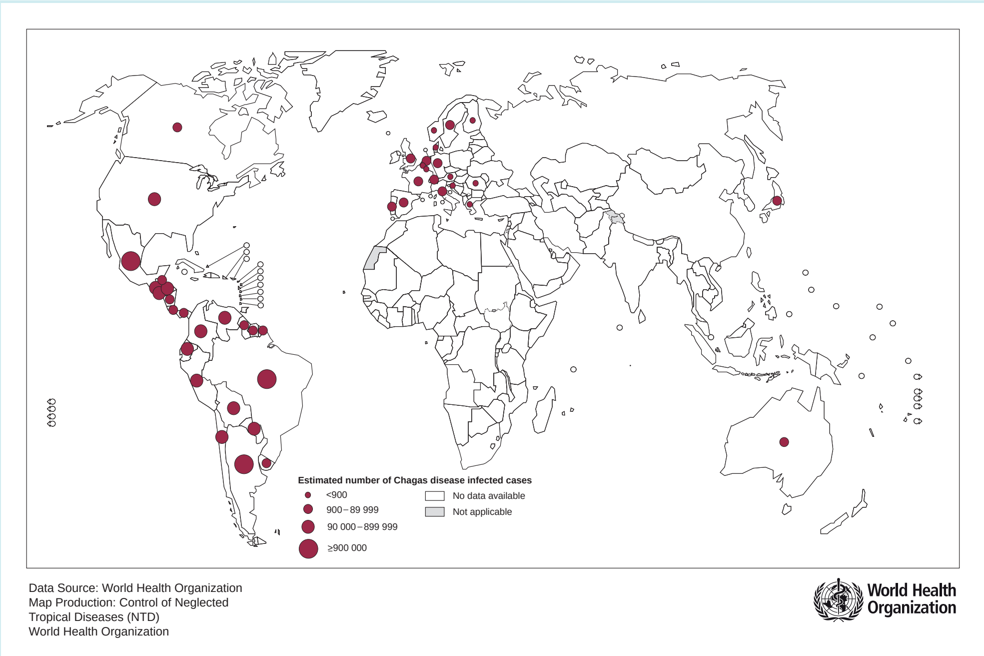
Chagas disease (American trypanosomiasis)

In most cases, symptoms of Chagas disease are absent or mild, but can include fever, headache, enlarged lymph glands, pallor, muscle pain, difficulty in breathing, swelling and abdominal or chest pain. In less than 50% of people bitten by a triatomine bug, characteristic first visible signs can be a skin lesion or a purplish swelling of the lids of one eye.

The disease can then become chronic, causing heart disorders, digestive and/or neurological problems. In later years, the infection can lead to sudden death or heart failure caused by progressive destruction of the heart muscle.

Antiparasitic benznidazole or nifurtimox can provide effective treatment if given soon after infection. There is no vaccine for Chagas disease.

Child with swelling of the eye lids (known as the Romaña sign) waiting to be seen by a doctor in Sonsonate, El Salvador



Global distribution of cases of Chagas disease based on official estimates, 2006–2010

Burden

An estimated 10 million people are infected with Chagas disease worldwide, mostly in Latin America where it is endemic. Once totally confined to the Region of the Americas, Chagas disease has spread to other continents due to increased travel and migration.

Transmission

Trypanosoma cruzi is mainly transmitted to humans through the infected faeces of blood-sucking triatomine bugs. These bugs typically live in the cracks of poorly constructed dwellings in rural areas and suburban slums.

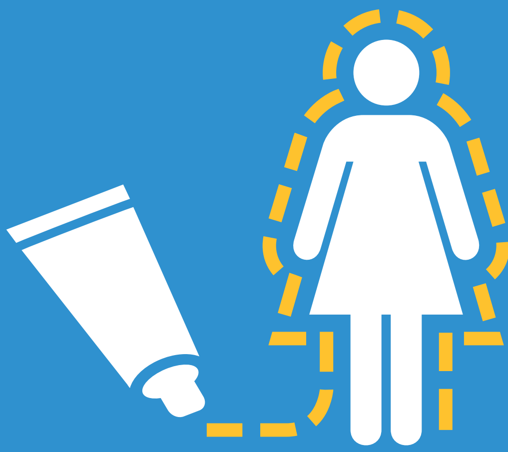
The bugs become active at night and typically defecate when they bite a person, often on exposed skin such as the face, hence the name 'kissing bugs'. The parasite is transmitted when the person rubs the area of the bite, thereby putting the faeces in contact with the bite, other skin breaks or mucous membranes of the eyes or mouth.

Other modes of transmission occur through contamination of food, frequently generating outbreaks especially in hot and humid climates. Transmission can also occur through transfusion of contaminated blood, from mother to child during pregnancy or delivery (congenital transmission), and, far less frequently, through organ transplantation or laboratory accident.

The distribution of vectors and wild reservoirs of *T. cruzi* in the Americas extends from the United States of America to Argentina and Chile. More than 150 species of triatomine bugs and more than 100 species of mammals, mostly wild species, maintain *T. cruzi* infection in nature, so it is not possible to eradicate Chagas disease.

Chagas disease has spread to other countries by migrants through transfusion and organ donation. Increasing population movement has increased the possibility of establishing vector transmission in areas where triatomine bugs are found but do not yet carry the disease, for example in Asia.

Section 3: Prevention and control



The time has come to utilize the full potential for vector control in the large-scale reduction of vector-borne diseases

The need is most acute for dengue fever, chikungunya, leishmaniasis and Chagas disease for which there is no straightforward method of treatment nor an effective vaccine.

A number of interventions to control and prevent vector-borne diseases exist. Some will be more appropriate than others, depending on factors such as:

- local ecology and behaviour of the vector species, including its habitats, flight range, feeding preferences and seasons
- local epidemiology of the disease
- human activity such as irrigation and animal farming
- socioeconomic conditions of affected communities
- cultural context
- feasibility of applying interventions in specific settings acceptable to the population
- environmental change

© UNHCR/S Hoibak

Some interventions currently in use include:

Long-lasting insecticidal nets

Insecticide-treated bednets are one of the most efficient and cost-effective ways to protect against mosquito-borne diseases, particularly malaria.

WHO therefore recommends that everyone who is at risk of malaria sleeps under a long-lasting insecticidal net every night. Between 2004 and 2013, international donors funded over 700 million bednets to protect families against malaria in sub-Saharan Africa.

Nets should be checked regularly for holes and replaced every 2–3 years. WHO publishes a list of recommended bednets: http://www.who.int/whopes/Long_lasting_insecticidal_nets_29_Oct_2013.pdf

A community health worker in Nigeria demonstrates how to renew a bednet with insecticide
© WHO/TDR

Bednets can also protect against sandflies and triatomine bugs. Trials of insecticide-treated nets in Afghanistan and the Syrian Arab Republic have demonstrated protective efficacy against cutaneous leishmaniasis, and observational studies in Bangladesh, Nepal and Sudan suggest they can protect against visceral leishmaniasis (16-22).

Nets should be checked regularly for holes and replaced every 2–3 years

Indoor residual spraying

Indoor residual spraying
© B Stewart, RTI International

Indoor residual spraying with insecticides is the most widely used method to control mosquitoes. It is also an effective way to reduce sandflies and bugs inside homes. At least 80% of houses in a targeted area need to be sprayed for maximum impact.

Indoor spraying is effective for 3–6 months, depending on the insecticide used and the type of surface on which it is sprayed. The insecticide DDT (see Box 1) can be effective for 6–12 months and continues to be used in several African countries. Meanwhile, longer-lasting forms of existing insecticides, as well as new classes of insecticides, are under development for use in indoor residual spraying programmes.

Factors to consider when selecting insecticides include safety for humans and the environment, efficacy (including duration of effectiveness), cost-effectiveness, acceptability and availability, and the capacity and resources for safe, effective application and disposal of waste.

For a list of WHO recommended insecticides for indoor spraying against malaria vectors: http://www.who.int/whopes/Insecticides_IRS_Malaria_25_Oct_2013.pdf

At least 80% of houses in a targeted area need to be sprayed

Box 1: DDT

DDT (dichlorodiphenyltrichloroethane) was first used as an insecticide to control vectors that spread malaria, typhus and dengue during the 1940s. It was used extensively in agriculture until increasing environmental and safety concerns in the 1960s led most developed countries to ban its agricultural use. Spraying programmes using DDT were also curtailed around the same period, mostly because mosquitoes had developed resistance to the widely used chemical.

Many malaria-endemic countries have replaced DDT with alternative insecticides, mostly pyrethroids but, in some cases, this has compromised the efficacy of vector-control programmes. For example, in South Africa the switch from DDT to pyrethroids in 1997 soon resulted in the reappearance of *Anopheles funestus*, a major malaria vector, eliminated from the country for decades and found to be resistant to pyrethroids. This reappearance resulted in severe malaria outbreaks, which justified re-introduction of DDT in 2000. Since then several other countries in Africa have re-introduced DDT.

DDT has the longest efficacy of all insecticides currently used for indoor residual spraying. It can last 6–12 months, compared to 3–6 months for pyrethroid-based insecticides. Alternative insecticides would require more than two spray cycles per year which would be very difficult and expensive to achieve in most settings.

The production and use of DDT is strictly restricted by an international agreement known as the Stockholm Convention on Persistent Organic Pollutants. The Convention's objective is to protect both human health and the environment from persistent organic pollutants.

WHO re-evaluates the risks that DDT poses to human health whenever there is significant new scientific information. An expert consultation in 2010 concluded that levels of exposure reported in studies were below levels of concern but that strict procedures must be followed to protect both residents and workers.

More information on the safe use of DDT:
http://www.who.int/malaria/publications/atoz/who_htm_gmp_2011/en/index.html

Outdoor spraying

Space-spraying activity outside a public building during a chikungunya outbreak in Mauritius, 2006
© WHO

Spraying outer surfaces of domestic animal shelters, outdoor latrines and other damp places can help control sandflies.

Aerial spraying of larvae breeding sites in fast-flowing rivers has been successful in helping to control blackflies which transmit onchocerciasis.

Aerial spraying has also been used to control mosquitoes during epidemics of dengue and yellow fever. If used early in an epidemic, emergency space spraying may reduce the intensity of virus transmission and provide time for the introduction of longer-term measures.

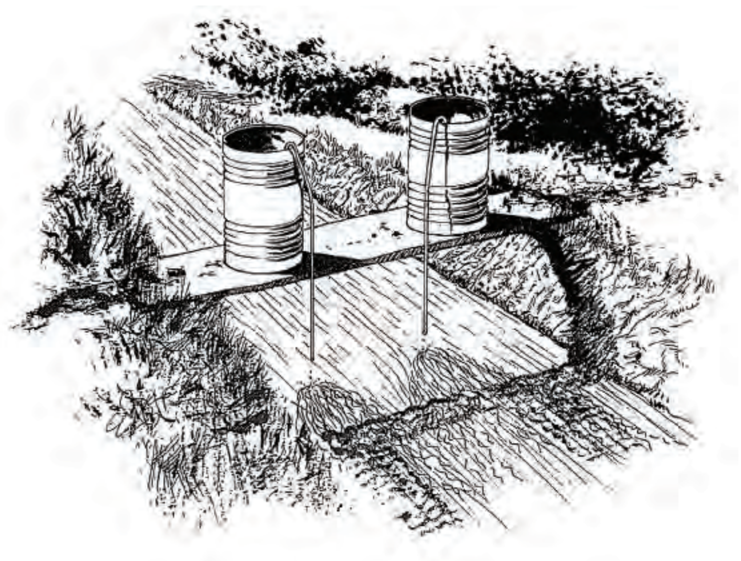
While tick control can be difficult as animal carriers are numerous and widespread, acaricides (chemicals that kill ticks) can be used successfully in well-managed livestock production facilities when required. Animals at risk of carrying Crimean-Congo haemorrhagic fever should be treated with pesticides two weeks prior to slaughter.

Addition of chemicals to water

Addition of insecticides to drinking water storage containers can be effective at reducing mosquito larvae where there is significant risk of diseases such as dengue and chikungunya fever.

However, extreme care must be taken when treating drinking water to avoid dosages that are toxic to humans. WHO publishes guidelines on the use of pesticides for vector control in domestic water storage: http://www.who.int/water_sanitation_health/gdwqrevision/whopes/en/

Some countries have successfully used chemicals to control snail populations in irrigation canals and small streams.



Chemical control of schistosomiasis: molluscicide is slowly released from a barrel into flowing water (15)

© J Rozendaal

Other insect repellents

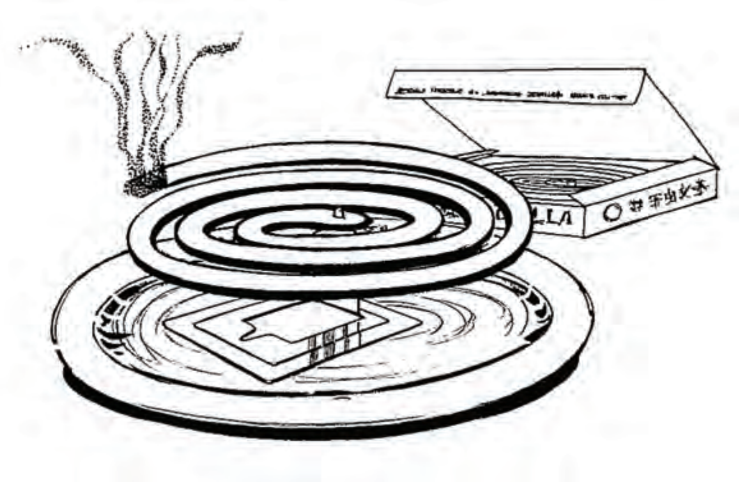
Insect repellents in the form of coils, vaporizing mats, aerosols and insecticide-impregnated curtains can also be effective in deterring and killing mosquitoes and sandflies in and around houses.

Coils usually have a synthetic pyrethroid as the active ingredient. One coil is effective through the night in an average-sized bedroom, unless the room is particularly draughty, which will cause the insecticide to dilute and the coil to burn faster. Special coil containers have been developed to solve this problem.

Insecticide vaporizing mats are used on small devices plugged into an electrical point. The mat is heated, causing the insecticide to evaporate.

Insecticide aerosol sprays are effective for an immediate knockdown and killing effect but will not necessarily keep the room free from mosquitoes for a whole night. WHO recommends the use of aerosol sprays in combination with a coil or bednet.

Use of repellents can help prevent dogs from carrying *Leishmania* parasites. Pyrethroid insecticides in shampoos, sprays, spot-ons, lotions and collars can be effective in controlling the spread in dogs. For example, dog collars impregnated with pyrethroid reduced the incidence of visceral leishmaniasis in children in a community trial in the Islamic Republic of Iran (23).



Mosquito coils are among the cheapest and most commonly used insecticide vaporizers (15)

© J Rozendaal

Environmental management

Reduce breeding habitats

For mosquitoes

Water-storage containers can be designed to prevent access by mosquitoes for laying their eggs. Containers should be fitted with tight lids or, if rain-filled, with tightly-fitted mesh screens to allow rainwater to be harvested from roofs while keeping mosquitoes out.

Domestic water storage containers should be emptied and cleaned regularly.

For freshwater snails

Regular drainage of water bodies, lining of canals and drains with concrete, and removal of vegetation from water bodies can be effective. Planting trees provides another means for draining swamps and other snail habitats. In China, *Oncomelania* snails were buried under soil dredged from canals and drains.

A research project on improving community members' understanding of how mosquitoes breed in open water containers and encouraging them to reduce the number of unnecessary containers in Bangkok, Thailand

Biological control

Biological control is a method of controlling mosquitoes and other vectors through the introduction of parasites, predators or other living organisms. Larvivorous fish and copepods (small crustaceans) are effective in controlling the larvae of *Aedes* mosquito. In many countries, small ornamental fish are introduced in water storage tanks to feed on the larvae.

Regular monitoring and restocking of these organisms is important for sustained control. Only native species should be used because exotic species may escape into natural habitats and threaten indigenous fauna.

A vector control programme in Viet Nam using copepods in large water-storage tanks, combined with source reduction, successfully eliminated *Ae. aegypti* in many communes and has prevented dengue transmission for a number of years.

Azolla is an aquatic plant that grows on the surface of water, making it difficult for larvae to reach the surface to breathe. It has been successfully used to control malaria-carrying mosquitoes in rice fields in the United Republic of Tanzania.

Fish are used to reduce mosquito larvae for malaria control in Timor-Leste
© WHO/MA Heine

Genetic control

Genetic control strategies aim either to suppress target populations or to introduce a harm-reducing trait. Several methods are under development and the first field trials are showing promising progress. Examples include genetically-engineering mosquitoes or introducing *Wolbachia* bacteria so that they cannot reproduce. Other studies have succeeded in modifying mosquitoes so that they can no longer transmit dengue parasites.

Waste management

Empty tins, plastic bottles, unused drums, coconut shells and used car tyres can serve as important breeding sites for mosquitoes.

Discarded tyres should be collected, recycled or disposed of carefully in waste transformation facilities (e.g. incinerators, energy-production plants, or lime kilns fitted with emission control devices). Insisting that people buying new tyres must return their old tyres may provide an incentive for better management and disposal of old tyres.

Stagnant water and rubbish in a street in Fortaleza, Brazil, allows Aedes mosquitoes to breed and infect people with dengue

© WHO/TDR

Household rubbish, particularly damp, organic matter, is a favoured habitat for sandflies so all garbage should be disposed of properly, away from human settlements.

Housing modification

- Human settlements should be located away from sandfly habitats.
- They should be fitted with door and window screens to help keep insects out.
- Efforts need to be made to keep plaster walls and concrete floors in good condition, with cracks and other possible entry points sealed up against all vectors, particularly sandflies and triatomine bugs.
- Air conditioning and/or fans keep mosquitoes away effectively.

Window screens manufactured and installed in Colombian communities to prevent Aedes *mosquitoes from getting into homes and infecting people with dengue*
© WHO/TDR

Personal protection

For individuals, personal protection against insect bites represents the first line of defence against many vector-borne diseases.

- Insect repellents are substances applied to exposed skin or clothing to protect against mosquito, sandfly and tick bites. The active ingredient in these repellents is most commonly a compound called DEET (N,N-Diethyl-meta-toluamide) or two other recently approved compounds IR3535 and KBR3023. Repellent should be applied to the neck, wrists and ankles, avoiding contact with eyes, nose and mouth. When applied to skin, the repellent effect may last from 15 minutes to 10 hours, depending on climate, the formulation of the product and its effect on specific vector species. The effect lasts longer when applied on clothes.

- Long sleeved, light-coloured shirts and trousers will help protect against mosquito, sandfly and tick bites. Clothing can be treated with products that contain permethrin. Pre-treated outdoor clothing is commercially available and can remain protective for up to 70 washes (24).

- In tick-infested areas, trouser legs should be tucked into socks and heavy boots worn when walking in rural or forested areas. Before entering homes, clothing, bags and other belongings should be examined thoroughly for ticks. If possible, bathe and conduct a full-body tick check within two hours of returning home (24). Ticks should be removed with tweezers as soon as they are discovered.

- People should avoid places and times when vectors are active. For example, by staying inside during peak biting hours (e.g. from dusk to dawn for malaria-carrying mosquitoes) and by avoiding walking in wooded areas with tall grass where ticks are found.

- In areas where schistosomiasis occurs, people should avoid contact with fresh water (lakes, slow-running streams). Where contact cannot be avoided (e.g. irrigation workers visiting a schistosomiasis-infested area), protective boots are recommended.

Medication

Travellers are encouraged to consult a medical professional if possible 4–6 weeks before departure to discuss how they can protect themselves against vector-borne diseases during their travels.

International travel and health published by WHO provides detailed information on how travellers can best protect their health before, during and after they travel (11): http://www.who.int/ith/en/

A baby receiving artemisinin-based combination treatment for malaria from a community health worker in Nigeria
© WHO/TDR

Prophylaxis and preventive therapies

Travellers may be prescribed antimalarial medicines as prophylaxis if travelling to malaria-endemic areas. In areas of moderate to high malaria transmission in sub-Saharan Africa, WHO also recommends intermittent preventive treatment with antimalarial medicines for pregnant women and infants, as well as seasonal malaria chemoprevention for children under 5 years of age living in areas of highly seasonal transmission.

Mass treatment

Lymphatic filariasis

The most effective way to interrupt transmission of lymphatic filariasis is to give single doses of albendazole plus either diethylcarbamazine or ivermectin to the entire population at risk every year for at least 5 years.

Schistosomiasis

Treatment with praziquantel several times during childhood is likely to prevent schistosomiasis in adulthood. The drug has been used successfully over the past 30 years to control schistosomiasis in many countries. In 2012 more than 42 million people, most of them living in sub-Saharan Africa, were treated for schistosomiasis.

Onchocerciasis

WHO recommends large-scale treatment with ivermectin of populations living in areas affected by onchocerciasis at least once yearly for about 10 to 15 years.

Where *O. volvulus* co-exists with *Loa loa*, another parasitic filarial worm that is endemic in several African countries, there is a risk of adverse reaction to ivermectin treatment. WHO has published recommendations for management of any severe adverse events that may occur.

A community drug distributor carrying ivermectin and a dose-pole during an onchocerciasis treatment campaign, is making her way to a remote village in Cameroon

Vaccines

Vaccines are not yet commercially available for dengue or malaria but, for both diseases, promising vaccines are under development.

Japanese encephalitis

Japanese encephalitis vaccination is recommended for travellers who plan to spend one month or more in endemic areas during the transmission season. This includes long-term travellers, recurrent travellers, or expatriates based in urban areas who may visit rural or agricultural areas during a high-risk period of virus transmission.

Tick-borne encephalitis

Tick-born encephalitis vaccination is recommended for people living in, or planning to camp or hike, in rural or forested areas where the disease occurs.

Yellow fever

Vaccination is the most important preventive measure against yellow fever. The vaccine is safe, affordable and highly effective, and a single dose of yellow fever vaccine provides life-long immunity.

Yellow fever is the only disease for which countries may require proof of vaccination as a condition of entry under the International Health Regulations.

Blood and body fluid safety

Chagas disease and Crimean-Congo haemorrhagic fever are two vector-borne diseases that can also be transmitted by contact with blood, secretions, organs or other bodily fluids of infected people (or animals).

Countries where Chagas disease is endemic should:

- Screen blood donors.
- Test organ, tissue and cell donors and receivers.
- Screen infected pregnant women, with newborns and siblings, for early detection of possible infection. The diagnosis of an infected newborn can be made at birth by detecting parasites directly in the umbilical cord or by blood test, or by detecting antibodies against *T. cruzi* when the infant is aged eight months.
- Implement standard safety protocols (laboratory coats, gloves, face masks, caps and glasses) for the prevention of laboratory accidents.

In countries where Crimean-Congo haemorrhagic fever occurs:

- People handling animals during slaughtering or butchering should wear protective clothing and animals should be treated with pesticides two weeks prior to slaughter.
- Health workers should follow WHO recommendations for infection control when caring for people with suspected Crimean-Congo haemorrhagic fever. Hospital-acquired infections can occur due to improper sterilization of medical equipment, reuse of needles and contamination of medical supplies.

Food safety

- In countries where Chagas disease occurs, strict hygiene practices in food preparation, transportation, storage and consumption can prevent contamination of food with the faeces of triatomine bugs.
- Tick-borne encephalitis can be transmitted in unpasteurized dairy products from infected goats, sheep and cows.

Section 4: Meeting challenges in the control of vector-borne diseases

Emerging insecticide resistance

Insecticide resistance is a major threat to existing vector control methods. This is largely due to heavy reliance on a single class of insecticides, the pyrethroids. Pyrethroids are not only highly effective, but are also the least expensive of the four classes of insecticides available for public health vector control. In some areas, however, resistance to all four classes of insecticides (temephos, methoprene, pyriproxyfen and novaluron) has been detected.

Long-lasting insecticidal nets and indoor residual spraying remain highly effective tools for malaria control. However, urgent action is required to prevent further development of resistance. WHO's *Global Plan for Insecticide Resistance Management in Malaria Vectors* sets out a coordinated strategy for all partners working in malaria control, including governments (together with other sectors such as agriculture and finance), donor organizations, United Nations agencies, and research and industry partners (25).

Vectors of dengue and leishmaniasis are also becoming resistant to insecticides, highlighting the need for an integrated approach for effective management in countries where diseases overlap.

WHO urges disease-endemic countries to assess the state of insecticide resistance locally, and to put in place comprehensive insecticide resistance management strategies. In parallel, endemic countries are encouraged to design a monitoring plan and build capacity to handle and interpret data about resistance. Through careful management, endemic countries can delay the evolution of resistance, preserve the effectiveness of existing insecticides and even reverse resistance in some settings.

Residual insecticide spraying of a rural peridomestic human dwelling
© Chagas National Program of Bolivia, 2009

Lack of expertise in vector control

The expertise of entomologists is critical to guiding vector control; however, the world is facing an extreme shortage of entomologists. Very few African countries have entomology programmes at undergraduate university level and some countries have only a handful of expert entomologists.

A mosquito survey in Timor-Leste
© WHO/M Heine

Given the size of investment needed for controlling vector-borne diseases and the critical role of vector control, surprisingly little has been done to build local infrastructure and skills needed to improve efficiency, monitor impact and sustain coverage with vector control interventions.

WHO calls for countries to increase their investment in training people with entomological skills, as well as the corresponding infrastructure (insectaries and entomological laboratories) to support them. Stronger collaboration between national control programmes, universities and training institutions is required, to provide better training opportunities for potential entomologists and improve employment and career prospects.

Surveillance

Surveillance of vectors and their diseases is key to measuring the effectiveness of interventions. In many high-burden settings, however, there is almost no data on these diseases or their vectors.

Surveillance of vector-borne diseases should be part of the national health information system, with data on disease cases and deaths collected routinely. Other data on environmental risk indicators (such as mosquito breeding sites) and control measures taken are essential to monitoring the success of, and requirements for, vector control interventions.

Strengthened surveillance systems can benefit control of many vector-borne diseases at the same time. For example, a system of surveillance for Chagas disease has been recently implemented in areas such as the Amazon basin, where malaria is also transmitted. Malaria microscopy technicians are trained to identify blood parasites, such as *T. cruzi* parasites in malaria films, and detect acute Chagas disease in individual cases. This makes it easier to detect and control foodborne outbreaks and active transmission areas for the disease.

WHO also recommends that every country at risk of yellow fever has at least one national laboratory where basic yellow fever blood tests can be performed. Any laboratory-confirmed case of yellow fever must be fully investigated, particularly in any area where most of the population has been vaccinated. Investigation teams must have the capacity to assess and respond to the outbreak.

Sanitation and access to safe drinking water

Poor sanitation and lack of access to clean drinking water allows many vectors to thrive.

WHO recommends piping water to households rather than drawing water from wells, communal standpipes, rooftop catchments and other water-storage systems. But it is important to ensure that water supplies are sufficiently regular and reliable so that people are not compelled to store water in containers that serve as mosquito larval habitats – such as drums, overhead or ground tanks, and concrete jars.

As traditional water storage practices may persist even when reliable supplies are available, the installation of reliable piped water supplies in houses should be accompanied by communication that discourages traditional storage practices.

Pesticide safety

Pesticide poisoning is a serious public health problem that disproportionately affects infants and children – partly because of their smaller size; differing metabolism; and rapidly growing and developing organs.

For this reason, many communities will be reluctant to add chemicals to domestic water, particularly drinking water. And if they are used, it is vital to ensure that pesticides are used at safe levels.

The International Programme on Chemical Safety (IPCS) has assessed the toxicity of the compounds methoprene, pyriproxyfen and temephos and the active ingredients in *Bacillus thuringiensis serovar israelensis (Bti)* to determine their safety for use as mosquito larvicides in drinking water. However, the safety of the active ingredients in the final formulation varies from product to product and requires further study, as do the possible microbiological contaminants in formulations of *Bti*.

WHO's *Guidelines for drinking-water quality* (26) provide authoritative guidance on the use of pesticides in drinking water. A 2010 survey found that 90% of 107 countries endemic for, or at risk of, major vector-borne diseases follow WHO specifications for quality control when procuring pesticide products.

The WHO Pesticide Evaluation Scheme (WHOPES) was set up in 1960. WHOPES promotes and coordinates the testing and evaluation of pesticides for public health. It functions through the participation of representatives of governments, manufacturers of pesticides and pesticide application equipment, WHO Collaborating Centres and research institutions, as well as other WHO programmes. The main objectives of WHOPES are (a) to facilitate the search for alternative pesticides and application methods that are safe and cost-effective; and (b) to develop and promote policies, strategies and guidelines for the selective and judicious application of pesticides for public health use, and assist and monitor their implementation by Member States. WHOPES also works closely with Food and Agriculture Organization (FAO).

In January 2014, the 134th WHO Executive Board approved the International Code of Conduct on Pesticide Management. This landmark document published jointly with the FAO will serve as a voluntary standard of conduct for all entities engaged in or associated with the management of pesticides. The code of conduct aims to guide government regulators, international organizations, the pesticide industry, the food industry, the private sector, civil society and other stakeholders on best practice in managing pesticides throughout their lifecycle from production to disposal (27).

Environmental change

Climate change is likely to exacerbate the already-high impact of vector-borne diseases on the world's most vulnerable populations, including children, pregnant women, elderly people, nomads, poor urban populations, refugees and people living in post-conflict settings. A review of published scientific literature on climate change and infectious diseases suggests that these vulnerable populations should be the priority focus of research and policy change (28).

Changing climatic conditions, such as rainfall patterns, temperature and humidity, affect the number and survival rate of mosquitoes and some other vectors. The ambient temperature determines insects' reproduction rate, biting behaviour and survival. Moreover, the incubation period of pathogens inside vectors tends to be shorter at warmer temperatures. Distribution of mosquitoes and other vectors may therefore expand with increasing temperatures. Climate information is important therefore both to surveillance and forecasting trends of vector-borne diseases such as malaria (29–33).

But more research is required: lack of scientific knowledge remains a serious obstacle to evidence-based health policy change (34).

WHO's Special Programme for Research and Training in Tropical Diseases (TDR) has developed a workplan for research on the impact of climate and environmental changes on vectors and vector-borne diseases to enable better targeting of preventable vector-borne diseases (35). This workplan brings together vector control and environmental research with community-based interventions to enhance community access to interventions against vector-borne diseases and other infectious diseases of poverty in different social groups (including urban, rural and nomadic populations).

Section 5: How public health stakeholders can tackle vector-borne diseases

Effective, long-term vector control and disease elimination calls for strong, well-funded national control programmes, comprehensive national and regional strategies, supported by close collaboration among partners in the global public health community. Sustainable programmes require technical guidelines that set out clear standard operating procedures, and are well managed with efficient logistics, monitoring and evaluation.

Box 2: Integrated vector management

WHO promotes integrated vector management as the best approach to strengthen vector control in a way that is compatible with national health systems (36).

Key elements of integrated vector management include:

- evidence-based decision-making based on research
- robust methods of monitoring and evaluation
- close collaboration between the health sector and other government sectors, as well as the private sector
- optimal use of human and financial resources through a multi-disease control approach
- use of a range of interventions, often in combination and synergistically
- planning and decision-making delegated to the lowest possible administrative level
- advocacy and social mobilization to promote vector control in relevant agencies, organizations and civil society
- a public health regulatory and legislative framework
- engagement with local communities to empower them and ensure sustainability of programmes
- increased capacity-building at national and local levels based on a situational analysis

For example, in view of the overlapping geographical distribution of malaria and lymphatic filariasis in large areas of Africa, Asia and the Americas, and the fact that *Anopheles* mosquitoes transmit both diseases, WHO recommends the use of integrated vector management in:

- areas co-endemic for malaria and lymphatic filariasis; and
- areas in which the vectors of the two diseases are affected by the same vector control interventions (37)

WHO also recommends integrated control of the *Aedes* mosquito vectors of dengue in some urban areas with control of *Culex quinquefasciatus*, an important urban vector of lymphatic filariasis.

WHO encourages…

Governments to

- commit at all levels (national, regional and local) to adopt and implement effective vector control policies
- embed vector control in comprehensive disease control strategies
- rationalize the use of resources and structures through integrated vector management
- strengthen regulatory and legislative controls for vector control tools and methods

Ministries of health to

- improve surveillance and monitoring of vector-borne diseases
- adopt a multi-disease approach, i.e. integrate interventions to control and prevent vector-borne diseases with other disease interventions
- develop and implement comprehensive insecticide resistance management strategies and ensure timely resistance monitoring
- collaborate with other government sectors

Ministries of the environment to

- consider the impact on vectors for all development projects, including irrigation, hydroelectric dam construction, road building, forest clearance, housing development and industrial expansion
- improve access to safe drinking water and adequate sanitation to reduce contact with water infected with the *Schistosoma* parasites

Ministries of education to

- support awareness raising and behaviour change campaigns
- develop school-based curricula, actively encouraging teachers to focus on environmental hygiene and management to prevent and control vector-borne diseases. Students can serve as peer-educators and health 'ambassadors' in their families and neighbourhoods

An educational poster on how to prevent the triatomine bugs from nesting in homes and transmitting the parasite T. cruzi *that causes Chagas disease, Bolivia (Plurinational State of)*

Ministries of finance, planning and overseas development to

- recognize vector control as a national development issue
- integrate funding for vector control into disease control budgets

Local authorities to

- provide a critical link in translating national vector control policies into practice at the local level
- work in close partnership with communities

Environmental, neighbourhood and other community groups

- Create strong partnerships with government to tackle the social and environmental determinants of health together
- Engage in awareness raising activities
- Call for improved sanitation and protection of water sources
- Organize vector control activities such as vegetation and rubbish clearance
- Improve capacity of community members, community health workers and agricultural extension workers through short practical training courses on vector biology, ecology and control methods

Private sector and donors

- Donors and the private sector should work together to enhance collaboration and coordination of activities to sustainably support control programmes efficiently and effectively
- Provide incentives for the research and development of insecticides, next generation vector control tools, innovative medicines and diagnostic tools
- Initiatives should be well-coordinated with robust systems for monitoring, evaluation and reporting, as well as procedures for rapid identification and correction of problems
- For many diseases such as Chagas disease, schistosomiasis and leishmaniasis, WHO has run control programmes using medicines donated or subsidized by the private sector

Families and households

Individuals can make a significant contribution to vector control by:

- knowing which vectors carry disease in their local setting and when travelling
- using proven vector-control tools at home, such as insecticide-treated bednets, and protecting themselves against insect bites when travelling
- cooperating with local authorities for such interventions as indoor residual spraying programmes
- participating in community-based health education about reducing the risk of vector-borne diseases
- taking part in environmental management campaigns. e.g. reducing standing water that could provide a breeding environment for mosquitoes around homes

Conclusion

Vector-borne diseases are one of the greatest contributors to human mortality and morbidity in tropical settings and beyond. Although significant progress is currently being made in combating some diseases such as malaria, lymphatic filariasis and Chagas disease, other diseases such as dengue continue to spread and increase their number of cases at an alarming pace.

The silent expansion of mosquito vectors and their ability to develop resistance to insecticides threatens the gains made through vector control and calls for concerted planning and collaboration across sectors including health, agriculture and the environment. In areas where vector-borne diseases overlap, integrated management of insecticide resistance is essential, supported by adequate capacity of trained personnel and resources.

Environmental changes have also facilitated the recent spread of some diseases in rural areas. This has major implications for health systems, straining the limited resources in many developing countries. Events in the past five years – simultaneous outbreaks in several countries and the emergence of vector-borne diseases in new parts of the world – clearly highlight the increasing threat of these diseases to global public health.

Vector control programmes need to adapt to match the changing epidemiological patterns of new emerging threats. This will require increased research to develop a sustained approach to ecological and environmental changes in the years ahead.

References

1. European Centre for Disease Prevention and Control. [Internet]. Climate Change. [cited 2014 Mar 10]. Available from: http://www.ecdc.europa.eu/en/healthtopics/emerging_and_vector-borne_diseases/vector-born_diseases/Pages/index.aspx
2. The world health report 2004 – changing history. Geneva: World Health Organization; 2004.
3. Lozano R, Naghavi M, Foreman K, Lim S, Shibuya K, Aboyans V et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. The Lancet. 2012;380: 2095-2128.
4. Suaya JA, Shepard DS, Siqueira JB, Martelli CT, Lum LC, Tan LH et al. Costs of dengue cases in eight countries in the Americas and Asia: a prospective study. Am J Trop Med Hyg. 2009;80(5):846-855.
5. Guha-Sapir D, Schimmer B. Dengue fever: new paradigms for a changing epidemiology. Emerg Themes Epidemiol. 2005;2(1):1.
6. Meltzer MI, Riqau-Péres JG, Clark GG, Reiter P, Gubler DJ. Using disability-adjusted life years to assess the economic impact of dengue in Puerto Rico: 1984–1994. Am J Trop Med Hyg. 1998;59(2):265–271.
7. Global strategy for dengue prevention and control, 2012-2020. Geneva: World Health Organization; 2012. 35 p.
8. Global strategic framework for integrated vector management. Geneva: World Health Organization; 2004. WHO/CDS/CPE/PVC/2004.10.
9. Sustaining the drive to overcome the global impact of neglected tropical diseases. Second WHO report on neglected tropical diseases. Geneva: World Health Organization; 2013. WHO/HTM/NTD/2013.
10. World malaria report 2013. Geneva: World Health Organization; 2013. 284 p.
11. World Health Organization. [Internet]. Geneva: International travel and health. [cited 2014 Mar 10]. Available from: http://www.who.int/ith/en/
12. Centers for Disease Control and Prevention. [Internet]. Atlanta GA, USA: Lyme disease. [cited 2014 Mar 10]. Available from: http://www.cdc.gov/lyme/
13. Centers for Disease Control and Prevention. [Internet]. Atlanta GA, USA: Tickborne encephalitis. [cited 2014 Mar 10]. Available from: http://wwwnc.cdc.gov/travel/yellowbook/2014/chapter-3-infectious-diseases-related-to-travel/tickborne-encephalitis
14. Mbabazi PS, Andan O, Fitzgerald DW, Chitsulo L, Engels D, Downs JA. Examining the relationship between urogenital schistosomiasis and HIV infection. PLoS Negl Trop Dis. 2011;5(12):e1396.
15. Rozendaal JA. Vector control: Methods for use by individuals and communities. Geneva: World Health Organization; 1997.
16. Maroli M, Mizzon V, Siragusa C, D'Oorazi A, Gradoni L. Evidence for an impact on the incidence of canine leishmaniasis by the mass use of deltamethrin-impregnated dog collars in southern Italy. Med Vet Entomol. 2001;15(4):358-63.
17. Picado A, Das ML, Kumar V, Kesari S, Dinesh DS, Roy L et al. Effect of village-wide use of long-lasting insecticidal nets on visceral Leishmaniasis vectors in India and Nepal: a cluster randomized trial. PLoS Negl Trop Dis. 2010;4(1):e587.
18. Tayeh A, Jalouk L, Al-Kahaimi A. A cutaneous leishmaniasis control trial using pyrethroid-impregnated bednets in villages near Aleppo, Syria. Geneva: World Health Organization; 1997. WHO/LEISH/97.41 WHO/LEISH/97.41
19. Jalouk L, Al Ahmed M, Gradoni L, Maroli M. Insecticide-treated bednets to prevent anthroponotic cutaneous leishmaniasis in Aleppo Governorate, Syria: results from two trials. Trans R Soc Trop Med Hyg. 2007;101(4):360–367.

20. Ostyn B, Vanlerberghe V, Picado A, Dinesh DS, Sundar S, Chappuis F et al. Vector control by insecticide-treated nets in the fight against visceral leishmaniasis in the Indian subcontinent, what is the evidence? Trop Med Int Health. 2008;13(8):1073-85.

21. Ritmeijer K, Davies C, van Zorge R, Wang SJ, Schorscher J, Donqu'du SI et al. Evaluation of a mass distribution programme for fine-mesh impregnated bednets against visceral leishmaniasis in eastern Sudan. Trop Med Int Health. 2007;12(3):404–414.

22. Elnaiem DA. Use of pyrethroid impregnated bednets for the control of visceral leishmaniasis in eastern Sudan. Geneva: World Health Organization; 1996. WHO ID L3/1881/47 WHO ID L3/1881/47.

23. Gavgani AS, Hodjati MH, Mohite H, Davies CR. Effect of insecticide-impregnated dog collars on incidence of zoonotic visceral leishmaniasis in Iranian children: a matched-cluster randomised trial. Lancet. 2002;360(9330):374-9.

24. Centers for Disease Control and Prevention. [Internet]. Atlanta GA, USA: Lyme Disease: Preventing tick bites. [cited 2014 Mar 10]. Available from: http://www.cdc.gov/lyme/prev/on_people.html

25. Global plan for insecticide resistance management in malaria vectors (GPIRM). Geneva: World Health Organization; 2012. 132 p.

26. Guidelines for drinking-water quality, fourth edition. Geneva: World Health Organization; 2011. 564 p.

27. International code of conduct on pesticide management. Geneva/Rome: WHO/Food and Agriculture Organization of the United Nations; 2014. [cited 2014 Mar 10]. Available from: http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/code/en/

28. Kelly-Hope L, Thomson MC. Climate and infectious diseases. In: Thomson MC, Garcia-Herrera R, Beniston M, editors. Seasonal forecasts, climate change and human health. New York: Springer; 2008. 31 p. (Health and climate series: advances in global change research).

29. Omumbo JA, Lyon B, Waweru SM, Connor SJ, Thomson MC. Raised temperatures over the Kericho tea estates: revisiting the climate in the East African highlands malaria debate. Malar J. 2011;10:12. [cited 2013 Dec 5]. Available from: http://www.malariajournal.com/content/10/1/12

30. Boko MI, Niang A, Nyong C, Vogel A, Githeko M, Medany Bet al. Climate change 2007: impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, editors. Working group II contribution to the fourth assessment report of the intergovernmental panel on climate change. Cambridge: Cambridge University Press; 2007:433–467.

31. Brooks N, Adger WN, Kelly PM. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change. 2005;15(2):151–163.

32. Dube OP, Chimbari MJ. Documentation of research on climate change and human health in southern Africa. Denmark: University of Copenhagen; 2009.

33. Githeko AK, Ototo EN, Guiyun Y. Progress towards understanding the ecology and epidemiology of malaria in the western Kenya highlands: opportunities and challenges for control under climate change risk. Acta Trop. 2012;121(1):19–25.

34. Zhou G, Minakawa N, Githeko AK, Yan G. Climate variability and malaria epidemics in the highlands of East Africa. TrendsParasitol. 2005;21(2):54–56.

35. Githeko AK, Lindsay SW, Confalonieri UE, Patz JA. Climate change and vector-borne diseases: a regional analysis. Bull World Health Organ. 2000;78(9):1136–1147.

36. Making a difference: TDR strategic plan 2012-2017. Geneva: TDR, World Health Organization; 2012. 11 p.

37. Integrated vector management to control malaria and lymphatic filariasis. A position statement. Geneva: World Health Organization; 2012. 4 p.

World Health Organization

www.who.int/world-health-day