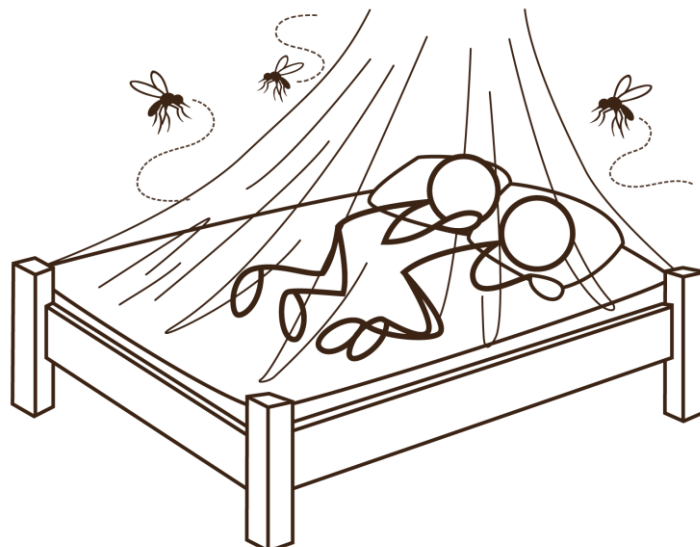


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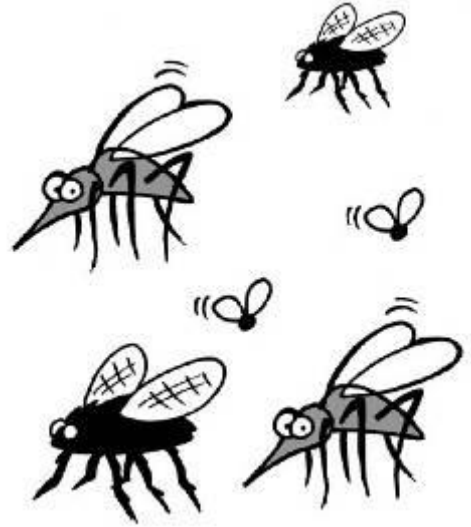


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1 What is a Vector?

A vector is a living thing that transmits a pathogen, such as mosquitos, flies and rodents. Vectors are common nuisances in many developing countries and they thrive in areas where there is poor environmental sanitation. For example, standing water provides breeding sites for mosquitos, garbage attracts rodents, and feces attract flies. These vectors can be carriers of many serious diseases.

- **Mosquitos** – Transmit a number of viral diseases such as **dengue fever**, **Japanese encephalitis** and **West Nile fever**. **Malaria** is caused by a protozoa that is passed on by mosquito and is the most important vector-borne disease in public health. About 3.3 billion people – half of the world's population – are at risk of malaria. In 2010, there were about 219 million malaria cases and an estimated 660,000 malaria deaths. People living in the poorest countries are the most vulnerable to malaria. In 2010, 90% of all malaria deaths occurred in Africa, mostly among children under five years of age (WHO, 2013).
- **Flies** – Carry pathogens on their bodies to uncovered food and drink, and to the faces, mouths and eyes of people. **Trachoma** is an eye infection that spreads from person to person. It is frequently passed from child to child and from child to mother, especially where there are shortages of water, numerous flies and crowded living conditions.
- **Rats, mice and other rodents** – Carry pathogens on their bodies and in their feces and urine. They act as vectors for various diseases including **hantavirus**, **typhus**, **leptospirosis** and the **plague**.



Fortunately, there are many measures that can be taken to control these vectors, many of which are appropriate for households and communities with limited resources.

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2 Mosquito Control

Different strategies can be used to reduce and prevent contact with biting mosquitos. Screens and nets, chemical controls (i.e. spraying bug repellent), environmental measures and human behaviour change are effective strategies to limit contact with pathogen-carrying mosquitos.

2.1 Mosquito Characteristics

Mosquitos are present worldwide with the exception of Antarctica. There are 41 different genera (types), which are subdivided into 3,300 species. There are three genera of mosquitos that are important in the transmission of disease: Anopheles, Culex and Aedes. They transmit various diseases and have different breeding and biting behaviours. The following table gives the most common characteristics for the different genera of mosquitos. However, there are many variations and exceptions depending on the species.

Mosquito Characteristics

Mosquito	Diseases	Breeding	Biting	Flight Range*
Aedes	Dengue fever, yellow fever, Arboviruses	Breeds in clean stagnant water, preferably shaded. Often breeds in small temporary pools caused by flooding. Commonly referred to as a “container breeder.” Eggs can survive being dried out.	Variable but most species are day biters with peak biting at dawn and dusk into early evening. Easily disturbed, but persistent biters, so will deliver multiple bites on several hosts. Bites are often painful.	Usually less than 150 metres, but can be up to 750 metres in rural settings and 570 metres in urban areas.
Anopheles	Malaria	Breeds in relatively clean, shallow water in any size of permanent water body, preferably shaded. Some species will breed in brackish, saline water.	Bites at night, mainly just after dark and before first light. Less easily disturbed, so usually only bite a few times.	Usually up to 2 kilometres, but some may fly many kilometres.
Culex	West Nile virus, lymphatic filariasis, Japanese encephalitis	Breeds almost anywhere, but favours dirty water with high organic matter (e.g., septic tanks, latrines)	Bites at night and is a persistent biter.	Usually less than 1 kilometre, but may fly several kilometres.

* The flight range of mosquitos was long thought to be quite limited. However, recent research suggests flight range is significantly longer.

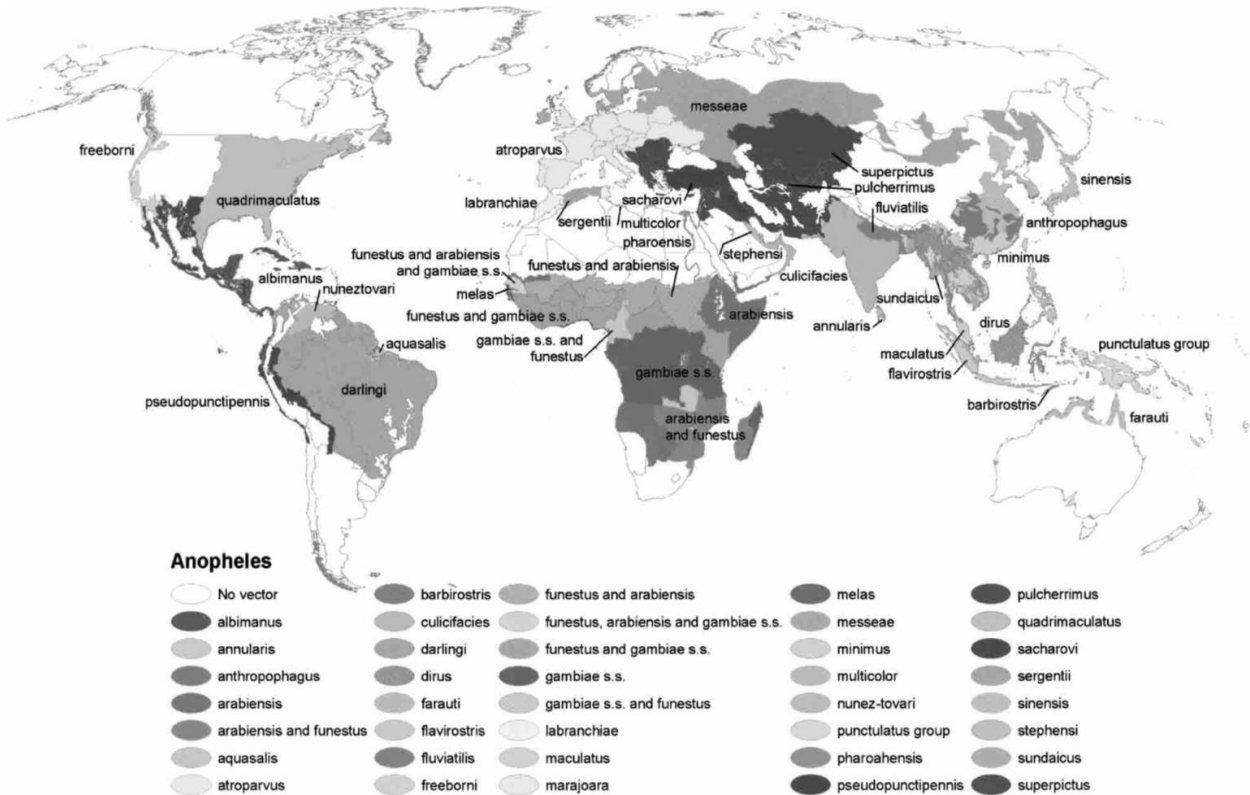
** Recent research has found that *Aedes aegypti* mosquitos have adapted to breeding in septic tanks and other large and dirty water reservoirs.

The average lifespan of a male mosquito is approximately two to three weeks. The lifespan of a female mosquito is usually longer and can be up to three months. The actual lifespan depends on the mosquito's species and the temperature of its environment. Female mosquitos will go through three egg laying cycles and will produce 300 to 1,000 eggs in a lifetime.

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The following map shows the specific species of Anopheles mosquito that are mainly responsible for malaria transmission in different countries. There are approximately 40 species of Anopheles mosquitoes that transmit malaria. Each species behaves differently and, therefore, requires its own control strategy. It is important to determine which types of mosquitos are responsible for disease transmission in the area where a control program is planned.

Global Distribution of Anopheles Mosquitos



(Kiszewski et al., 2004)

2.2 Mosquito Disease Transmission

Mosquitos feed for the most part on plant nectar and sap. It is only the female mosquito that bites humans and other mammals and birds. The female needs a blood meal, in order to take in protein, which is essential for egg production. It is during the blood feeding that the pathogens are passed from the mosquito to the human.

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2.2.1 Malaria

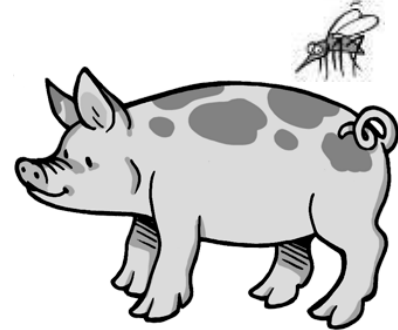
The following describes how malaria is transmitted from mosquitos to people:

1. A mosquito bites a person already infected with malaria protozoa.
2. Blood containing malaria protozoa is ingested by the mosquito.
3. The protozoa develop in the mosquito before becoming infectious (10-21 days depending on the species and local temperature).
4. The mosquito bites another person and injects malaria protozoa into their blood.
5. The protozoa develop, cause malaria in the person and become infectious again (7-30 days depending on type of malaria).

2.2.2 Japanese Encephalitis

The following describes how Japanese encephalitis is transmitted from mosquitos to people:

1. A mosquito bites a bird carrying the Japanese encephalitis virus (the bird is not affected).
2. The mosquito bites a pig and injects the virus into the pig.
3. The encephalitis virus reproduces and accumulates in the pig (the pig is not affected).
4. A mosquito bites the pig.
5. Blood from the pig has the Japanese encephalitis virus and is ingested by the mosquito.
6. The mosquito bites an uninfected person and injects the virus into their blood.
7. The virus infects the person who then becomes sick.



Mosquito biting a pig

2.2.3 Dengue Fever

The following describes how dengue fever is transmitted from mosquitos to people:

1. A mosquito bites a person already infected with the dengue fever virus.
2. Blood containing the dengue virus is ingested by the mosquito.
3. The virus replicates in the mosquito.
4. The mosquito is infectious for life and can transmit the virus to its offspring.
5. The mosquito bites an uninfected person and injects the virus into their blood.
6. The virus infects the person who becomes sick with dengue fever within 2-7 days.

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2.3 Mosquito Control

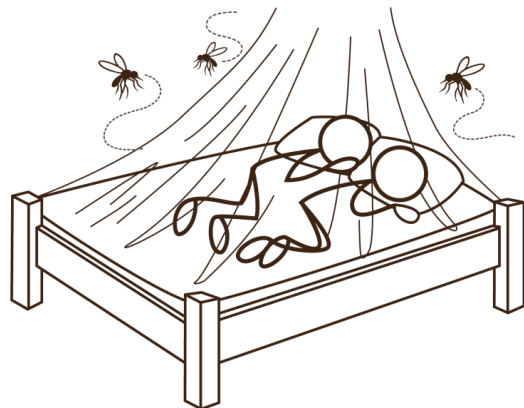
There are four main strategies for preventing and controlling mosquito borne diseases:

1. Screens and nets
 - Preventing mosquitos from entering buildings by using screens on doors and windows
 - Preventing mosquito bites by sleeping under bed nets
2. Chemical and biological methods
 - Coating bed nets with insecticide
 - Killing mosquitos either as adults or as larvae by using insecticides and larvicides
 - Burning mosquito coils with insecticidal and repellent properties
3. Environmental measures
 - Reducing the population and presence of mosquitos by removing breeding and resting sites
 - Reducing transmission by removing intermediate and amplifying hosts (i.e., In 1992, Singapore stopped pig breeding to prevent the transmission of Japanese encephalitis)
4. Personal protection and behaviour change
 - Wearing full-cover clothing or staying indoors during biting periods
 - Using mosquito repellent

2.3.1 Screens and Nets

Using mosquito screens and nets is often the simplest method to reduce or prevent mosquito bites inside the home and while sleeping, although it can be relatively expensive for the poor. Steel or plastic screen with a mesh size small enough to prevent mosquitos from being able to enter is available virtually everywhere. Installing screens on doors and windows will reduce the number of mosquitos, flies and other insects that enter the home. Some homes will require extra work and attention, especially when they have gaps between the walls and the roof.

Bed nets can be very effective at preventing mosquito bites. However, if the sleeping person lies against the net, then mosquitos can still bite through it. Using insecticide treated nets (ITN) improves the effectiveness of personal protection against mosquito bites. The insecticide adds a chemical barrier, which is deadly to mosquitos. Hanging an ITN in a room will also protect people who are not sleeping under the net. After a blood meal, the mosquito is heavier and needs to rest to allow the blood to be digested. If the mosquito lands and rests on the net it will be killed, preventing it from infecting anybody else.



Sleeping under a bed net

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Pre-treated insecticide nets are available, but still require re-treatment every four to six months. Despite the extra work, it may be worthwhile to purchase untreated nets and treat them yourself since the quantity and quality of pre-treated insecticide nets varies from ineffective to effective. Bed nets should be treated every four to six months and after washing. However, the low re-treatment rate is often considered one of the main drawbacks of ITNs (WHO, 2006). Awareness and education is necessary to ensure that people re-treat their nets. It can be better to arrange a community approach for re-treatment where large vats of insecticide are set up, so that people can dip their nets and then take home to dry. Long lasting insecticidal nets (LLIN) are also available and don't require people to reapply the insecticide.

Since the year 2000 there has been substantial funding and implementation of malaria control programs, including providing free ITNs. Much of international funding has been targeted to Africa, to countries with the lowest gross national income (GNI) per capita, and to countries with the highest malaria mortality rates (WHO, 2012).

By 2011, 32 countries in the African Region and 78 other countries worldwide had adopted the WHO recommendation to provide ITNs to all persons at risk for malaria. A total of 89 countries, including 39 in Africa, distribute ITNs free of charge. The percentage of households owning at least one ITN in sub-Saharan Africa is estimated to have risen from 3% in 2000 to 53% in 2012. The proportion of people sleeping under an ITN, representing the population directly protected, also increased from 2% in 2000 to 33% in 2012 (WHO, 2012).

Approximately 90% of people with access to an ITN actually use it, suggesting that efforts to encourage ITN use have been successful. The main barrier to increasing the number of at-risk people sleeping under an ITN is insufficient availability of nets. The proportion of the population sleeping under an ITN is higher in wealthier, urban areas, and lower among older children. It is anticipated that that differences in ITN access should decrease as programs move towards universal coverage (WHO, 2012).

2.3.2 Chemical Methods

Insecticides are chemicals that are used to kill insects, including mosquitos. A common approach is to apply an insecticide with a long-lasting effect to the interior walls of the home. Mosquitos or other insects are killed by the insecticide when they land on the walls. Indoor residual spray (IRS) insecticides need to be reapplied approximately every six months, depending on the type of insecticide and the wall material. IRS does not generally prevent people from being bitten, but it kills mosquitos after they have fed and are resting.

IRS is the most widely used malaria vector control method. It has been standardized and there are clear specifications for suitable equipment and insecticides. Field guidelines on technical and operational issues are available in almost all languages of malaria-endemic countries (WHO, 2006).

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Fogging and spraying insecticides over large outdoor areas is also common in some countries, especially in urban areas. This can have an immediate and dramatic effect on the population of insects in an area. However, the insect population will quickly recover unless the fogging is repeated regularly. To be effective, the timing of the application must coincide with the period in the day when the target mosquitos or insects are active, and it is most useful for mosquitos and insects that spend most of their lives outside of buildings.

Larvicides are a special type of insecticide that kills the larvae of insects. They can be applied to bodies and containers of water to kill mosquito larvae before they mature into mosquitos. They are especially useful when dealing with “container breeding” mosquitos (e.g., *Aedes* mosquitos), as breeding sites can be identified and larvicides easily applied.

2.3.3 Biological Methods

There are naturally occurring bacteria that act as larvicides, and they are being sold commercially in an increasing number of regions. Biological methods are growing in popularity as they are seen to be safer and less environmentally threatening than the chemical products. However, there is concern that the long-term effects of introducing new microorganisms into the environments are not fully understood.

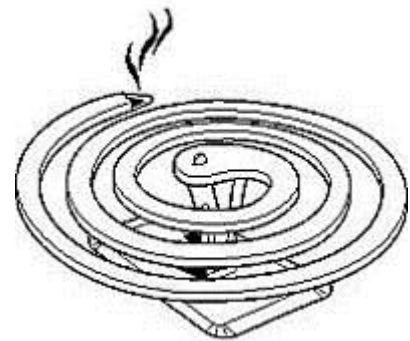
Bacillus thuringiensis var. israelensis (Bti) is a type of bacteria that kills the larvae of mosquitos, black flies and some other insects. There is no evidence to suggest that it is harmful to humans, livestock or other aquatic creatures. However, its effectiveness is affected by water quality parameters such as high organic content, temperature and pH. *Bti* has virtually no residual effect and therefore requires regular, repeated applications.

Bacillus sphaericus (Bs) is another type of bacteria that can kill some species of mosquito larvae. It is generally effective against *Anopheles* and *Culex* larvae, but not against *Aedes* or black fly larvae. It has a two to four week residual effect, and is effective in water with high organic content, although the residual effect is less.

Although they can be effective, biological control methods are not used on a large scale in malaria control. This is due to cost, and also to the operational and human resource requirements needed to apply the biological methods to all of the potential breeding areas. Another problem is that we don't know enough about mosquito breeding ecology and the local biology to effectively target biological methods.

2.3.4 Mosquito Coils

Using mosquito coils containing natural or synthetic insecticides and repellents is very common. The smoke produced when the coils burn also has a repellent effect and can kill mosquitos. Coils can be useful for dealing with mosquitos that bite in the evening and at dusk before people go to bed under their nets. However, there is concern that daily use of these coils over the long-term, especially in closed rooms, can contribute to lung disease.



Mosquito coil

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2.3.5 Environmental Measures

Environmental measures to reduce breeding and resting sites for mosquitos can be difficult to carry out effectively. The flight range of mosquitos varies from 0.5 to several kilometres. In some areas, there may only be a few locations within that 2 km radius where mosquitos can breed and that may be fairly easy to deal with. However, in other areas there may be many thousands of mosquito breeding sites within a 2 km radius.

Environmental measures to reduce mosquito populations include:

- Disposing wastewater using soak pits or infiltration trenches
- Disposing solid waste properly in sanitary landfills or covered pits, especially items that can hold water such as cans, bottles, tires and plastic bags
- Putting screens on water storage containers and tanks to prevent mosquitos from entering
- Constructing and maintaining drainage channels to avoid flooding and stagnant water
- Clearing standing water (e.g., flower and plant pots that contain standing water, blocked gutters and drains, covered and screened latrines and septic tanks)



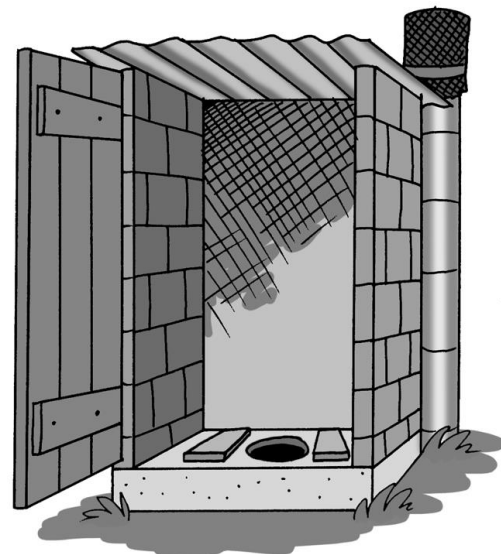
Disposing wastewater in a soak pit

3 Fly Control

Flies play a role in transmitting many diarrheal diseases. They lay their eggs in organic material that provide food for emerging maggots. Excreta found in unsanitary latrines is ideal for this, as is domestic food waste that is not properly disposed of. Flies pick up pathogens on their bodies when laying their eggs or feeding and then transport pathogens to people's food, tableware and faces.

Latrines are important to prevent flies and other insects from gaining access to the excreta or preventing them from exiting once inside. They can greatly reduce the volume of excreta that is flying around on flies. The number and accessibility of breeding and feeding sites can be reduced if everybody in a community practices safe excreta disposal and proper waste management. This would lead to a reduction in fly populations.

Flies also play a role in transmitting trachoma, an eye infection caused by the pathogen *Chlamydia trachomatis*. Flies are attracted to eye discharge and land on the face of an infected person, picking up the pathogen and then transporting it to the eye of a new person. The disease is especially prevalent in areas where there are shortages of water, numerous flies and

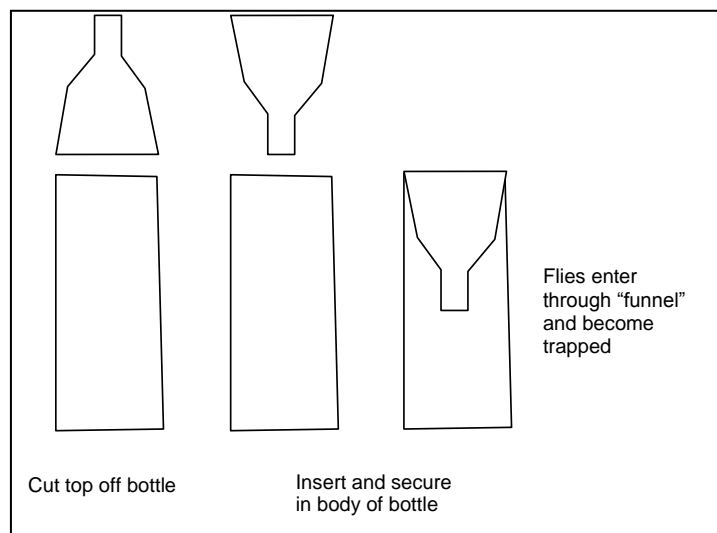
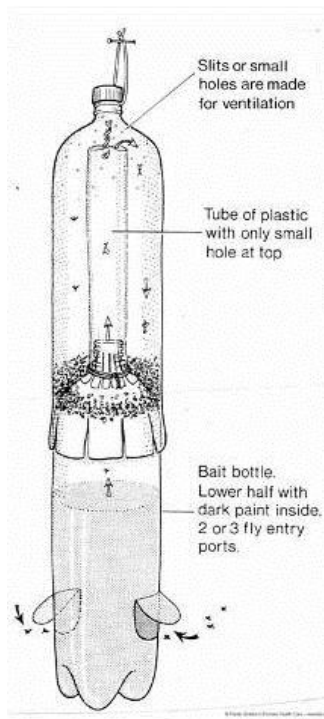


Ventilated improved pit (VIP) latrine to reduce flies and other insects

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crowded living conditions. The main interventions to prevent trachoma infection include properly disposing human and animal waste, reducing fly breeding sites and improving facial cleanliness (with clean water) among children at risk of disease. Good personal and environmental hygiene have been proven successful in reducing trachoma (WHO, 2001).

Using insecticides—similar to those used for mosquito control—can also significantly reduce fly populations. Other methods to control flies include using sticky fly papers and tapes, as well as simple traps. Fly traps can be made from used plastic bottles, as shown in the following illustrations. When the fly traps are full, the contents should be buried at least 15 cm below ground to prevent hatching larvae from emerging.



Fly traps made from used plastic water bottles
(Credit: Unknown)

4 Rodent Control

Rodents such as rats and mice transmit disease through a number of ways, such as:

1. Direct contamination through dirt and feces carried on their body
2. Bites or scratches (e.g., rat bite fever)
3. Fleas carried on their bodies that can transmit typhus and plague
4. Urine and feces that can transmit leptospirosis and hantavirus

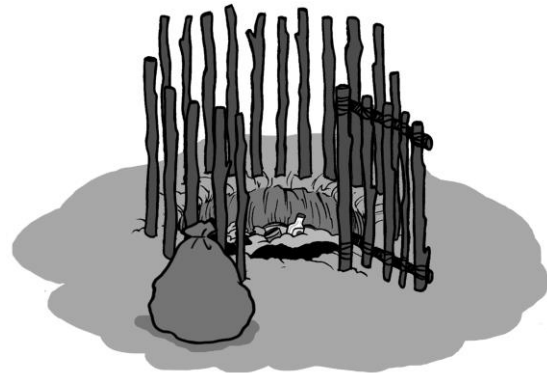
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Rats and other rodents can find their way into homes, as well as food and grain storage areas where they eat and destroy huge amounts of food annually. Controlling them reduces the risk of disease transmission and can also decrease food loss and spoiling.



4.1 Passive Control Measures

Prevention is better than cure. It is usually better and easier to prevent an infestation of rodents than to get rid of them once they are established. The number of rats and other rodents that are found in an area is closely linked to the availability of food, water and shelter. Properly disposing domestic waste will remove an easily available food supply. As well, using rodent-proof storage containers will limit the availability of food. Many traditional designs of grain stores have features that prevent rodents from entering the building. However, many modern grain stores do not have such protection.



Disposing waste in a small pit that is regularly covered with soil

Cutting grass and brush around buildings and keeping the surrounding area tidy and free of domestic waste can also deter rodents since they prefer to move along dark, sheltered pathways.

Cats and dogs (even just their scent) can deter rats and mice from entering a building and in some cases will even drive them out. Some cats and dogs are natural hunters; however, cats may be reluctant to attack a large adult rat.

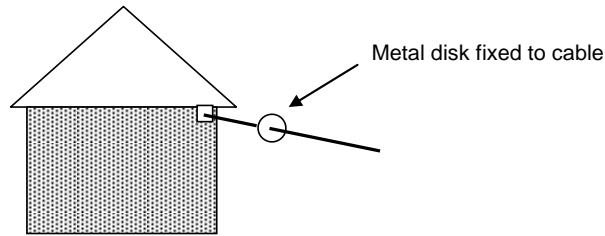
4.2 Rodent-Proof Buildings

Ensuring that a building is rodent-proof is not an easy task. Rats and mice can pass through extremely small holes or a crack in a wall (6 millimetres for a mouse and 12 millimetres for a young rat). Therefore, careful attention is needed to ensure that all cracks and holes are filled. Rodents are powerful and if they are used to entering a building at a particular place, it may be necessary to reinforce any repairs with steel mesh to prevent them from chewing their way back inside again.

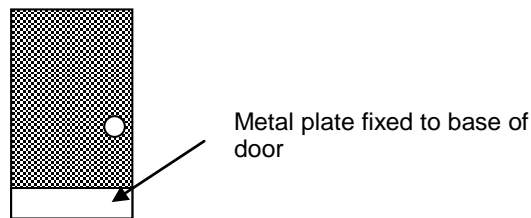
Other rodent-proofing measures include:

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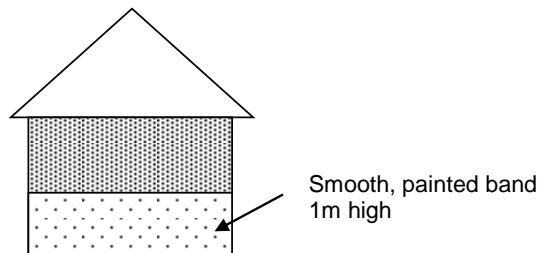
- Fixing metal disks on cables and pipes entering a building to prevent rodents from crawling along them



- Fixing steel sheeting to the bottom of doors and to the jamb to prevent rodents from gnawing on the edges



- If external walls have rough surfaces, plaster and/or paint a smooth band 1 metre high to create a slick surface to prevent rodents climbing up the walls



(Adapted from Hygnstrom *et al.*, 1994)

4.3 Active Control Measures

Plague and typhus are transmitted by fleas normally carried on the bodies of rats. When a rat is killed its fleas will normally transfer to another rat. However, if large numbers of rats are killed at one time, then there is a risk that the fleas will move to the nearest warm living thing, which may be a human. In areas where plague and typhus are common, rats should be treated for fleas before any attempt is made to kill them. This can be done by dusting rat runs with a powdered insecticide (e.g., deltamethrine or similar). The rats pick up the powder on their lower bodies and on their feet, and then it is spread through their fur during grooming.

Rodents can be surprisingly intelligent and cautious animals, and will often avoid traps laid for them. They will carefully investigate traps and bait boxes (i.e., boxes or tubes which use poisonous bait and prevent access to it by other animals or children) and avoid them if a member of their pack is harmed. A form of "bait and switch" can be done to get rodents used to feeding at the traps or bait boxes. Traps are laid with food but not set, and bait boxes are laid with poison-free bait. After the rodents are used to feeding there, then the traps are set and poison is placed in the bait boxes.

Traps and poison baits must be set in places where there is no danger to children or to domestic animals.

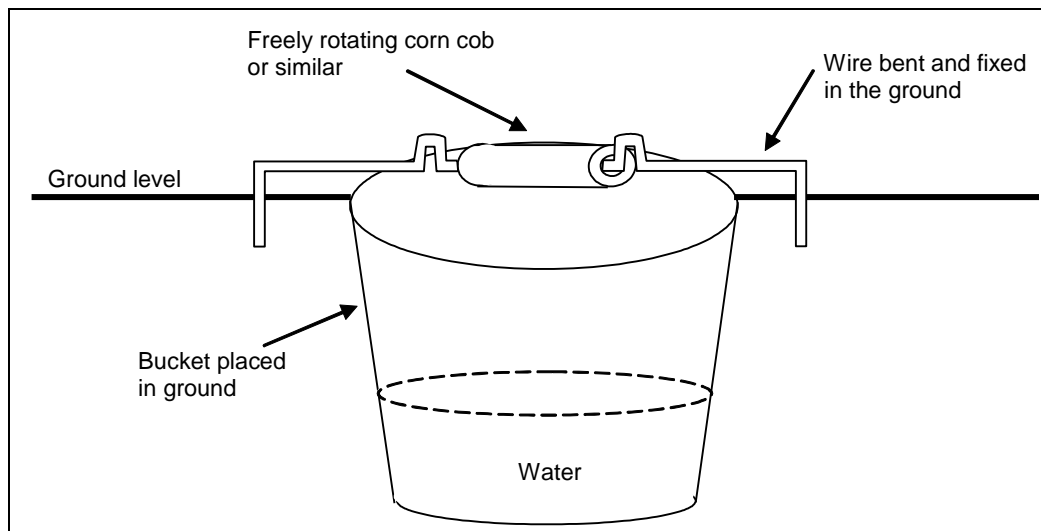
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Mechanical spring traps are available everywhere in the world and are usually sized to fit the rats or mice found locally. They should be baited with foods that are familiar to the targeted rodent population.

Rodent glue is available in many parts of the world. This is a very sticky glue which is applied to pieces of board and placed along rat runs. The glue can also be baited. The rats and mice stick to the glue and can then be killed. The advantage of rodent glue is that it is non-toxic and safe to use in food storage and preparation areas.

Box or cage traps catch rats and mice alive. They can then be killed or released somewhere far away from people's homes.

A **pitfall trap** is a simple but effective trap that can be made from a bucket, a corn cob and a piece of wire. The corn cob can be smeared with peanut butter or similar food to attract rats. The rat stretches over the bucket, places its front feet on the corn cob which spins around, and then falls into the bucket and drowns. The bucket should be wide enough so that the rat must use a long, unbalanced reach to the bait, and it should be deep enough to prevent the rat from escaping once inside.



4.4 Rodenticides

There are many different types of rodenticides designed to kill rats and mice. The rodenticide is applied to food which acts as a bait to attract rodents. As previously mentioned, rats are cautious of new foods. They may try a small piece and then wait to see whether they become sick. Therefore it is important to do the following:

- Use a bait and switch strategy
- Ensure that the rodenticide is tasteless and odourless
- Ensure that the poison has a delayed effect (at least one day, preferably longer)

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Rodenticides and the bait food should be placed in bait boxes. These are boxes or tubes which contain the bait and prevent access to it by other animals or children. Bait boxes should be placed along places where rats commonly run, or adjacent to areas where rodents are accustomed to feeding.

A problem with rodenticides is that there is no control over the location that the rat or mouse dies. Unpleasant smells can result if they die in a nest that is inside a wall or ceiling of a home. Some rodenticides (e.g., anticoagulants) cause dehydration. These are used in the hope that the rodent will leave the building in search of water.

Another important consideration is that the body of the dead rodent will be poisonous. This can be an issue for communities which traditionally eat rodents and where scavenging dogs, cats and pigs may eat the dead rodents.

If a large rodent control campaign is planned, especially if rodenticides are to be used, then local pest control experts should be consulted for advice and guidance.

(Adapted from MSF, 2010)

5 Additional Resources

Rozendaal, J. (1997). Vector Control: Methods for Use by Individuals and Communities. WHO, Geneva, Switzerland. Available at:
www.who.int/water_sanitation_health/resources/vectorcontrol/en/

- The manual provides practical information on major disease vectors and pests: mosquitos and other biting Diptera, tsetse flies, triatomine bugs, bedbugs, fleas, lice, ticks, mites, cockroaches, house-flies, water fleas and freshwater snails. For each group of vectors, information is provided on biology, public health importance and control measures. Chapters on house-spraying with residual insecticides and the safe use of pesticides are also included.

World Health Organization. Malaria Vector Control and Insecticide Resistance. Available at:
www.who.int/malaria/publications/vector-control/en/index.html

- This website provides a list of WHO publications that can be downloaded for free.

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