

Literature Survey: Dengue conditions in Singapore

February 7, 2017

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Dengue numbers in Singapore.

17. Which are the dengue hotspots in Singapore?
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21. What treatments are used to treat a dengue patient? What is the cost of treatment and medication?

1. Which animal causes maximum number of human deaths in a year?

Answer:

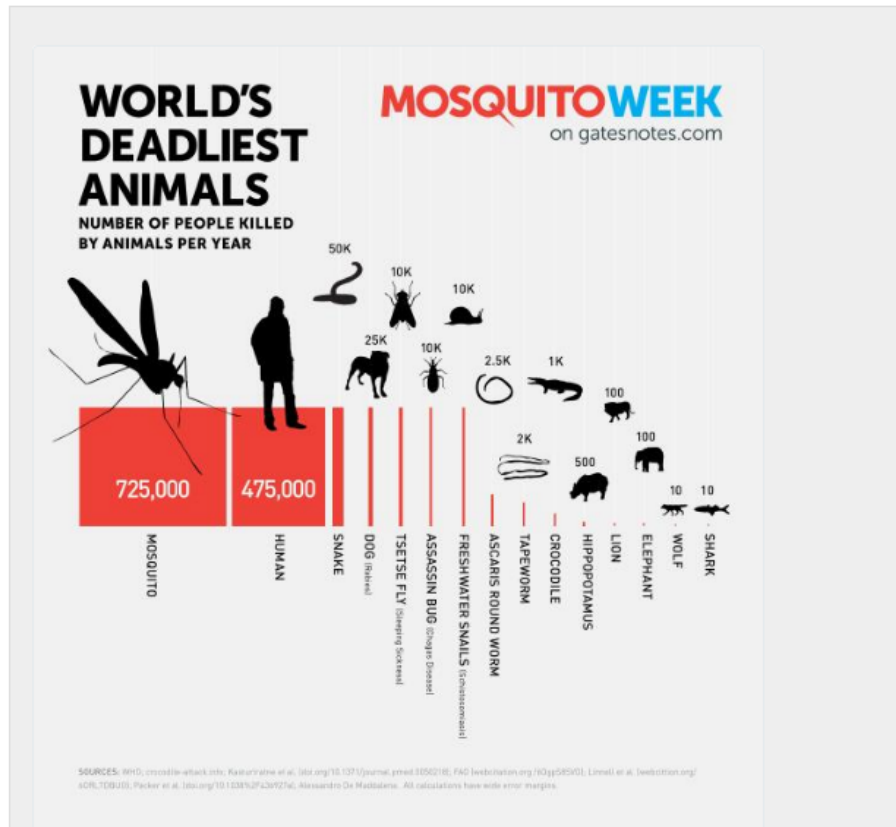


Figure 1: World's deadliest animals[1].

- According to WHO report, every year more than one billion people are infected with vector-borne diseases and more than one million people die from vector-borne diseases including malaria, dengue, yellow fever, lymphatic filariasis etc. Vectors are any living organisms that transmits infectious diseases between people or from animal to people.
- Many of these vectors are blood sucking insects that ingest disease-causing micro-organisms from the infected (virus carrying) host during a blood meal and later inject it into new host during their next blood meal. Mosquitoes are best known disease vectors. There are around 3500 species of mosquitoes. Some of these species have ability to carry many different diseases. Among these species, *Aedes Aegypti* (*Ae. aegypti*) is a primary vector that spreads dengue, Zika, chikungunya, and yellow fever[2].
- **Mosquitoes are effective transmitters:** Mosquitoes feed on blood. When feeding they pierce the skin like a needle and inject a saliva into a person's skin. This transmits the disease causing agents into the site. As mosquitoes fly, they can spread diseases more quickly than any contagious disease like Ebola[3]. 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 the risk of these diseases[2]. Nearly 700 million people get mosquito-borne illness each year and more than one million of them result in death[4].

Summary:

1. Mosquito being an effective transmitter of vector-borne diseases, is the deadliest insect causing around 1 million deaths per year by transmitting diseases like dengue, Zika, yellow fever, chikungunya etc.
2. There are around 3500 species of mosquitoes.
3. Nearly 700 million people get mosquito-borne illness each year.

2. What is dengue? How lethal is it?

Answer:

- Dengue is a mosquito-borne viral infection that affects infants, young children and adults. It is caused by four closely related viruses (DEN-1, DEN-2, DEN-3 or DEN-4). This illness causes flue-like illness and occasionally develops into potentially lethal complication called *severe dengue*[5]. The two most severe forms of dengue are Dengue Haemorrhagic Fever (DHF) and Dengue Shock Syndrome (DSS).

There is no specific treatment for dengue fever but early clinical diagnosis and careful clinical management often save lives.

- The incidence of dengue has grown dramatically around the world in recent decades. The actual numbers of dengue cases are under reported and many cases are misclassified. One recent estimate indicates **390 million dengue infections per year** (95% credible interval 284–528 million), of which **96 million (67–136 million) manifest clinically** (with any severity of disease).

Another study, of the prevalence of dengue, estimates that 3.9 billion people, in 128 countries, are at risk of infection with dengue viruses.

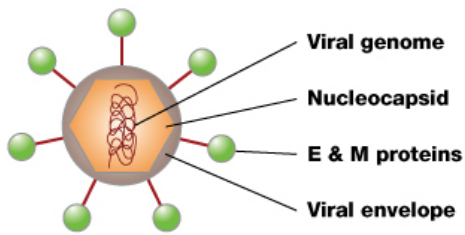
Member States in 3 WHO regions regularly report the annual number of cases. The number of cases reported increased from 2.2 million in 2010 to 3.2 million in 2015. Although the full global burden of the disease is uncertain, the initiation of activities to record all dengue cases partly explains the sharp increase in the number of cases reported in recent years[5].

About Dengue Virus :

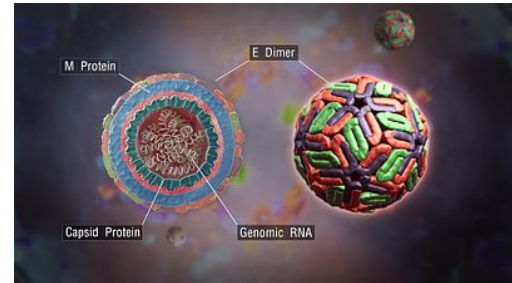
- Dengue virus (DENV) is a tiny structure that cause the most common arthropod-borne viral disease in man with 50–100 million infections per year.

It is a mosquito-borne single positive-stranded RNA virus of the family Flaviviridae; genus Flavivirus. Four serotypes of the virus have been found, all of which can cause the full spectrum of disease. All four DENV serotypes have emerged from sylvatic strains in the forests of South-East Asia.

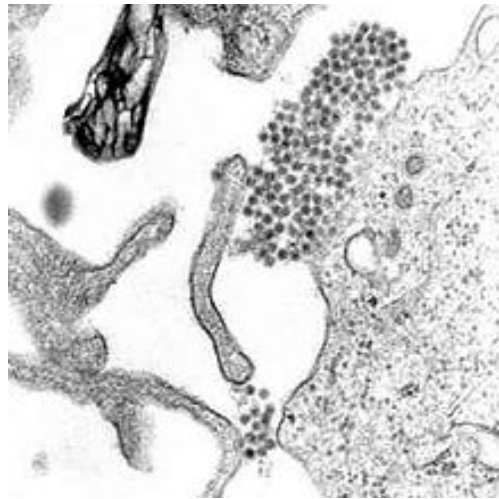
DENV infection can be asymptomatic or a self-limited, acute febrile disease ranging in severity[22].



(a) Dengue virus structure



(b) Structural components in Cross-section view of DNV



(c) TEM Micrograph showing DNV virions cluster

Figure 2: Dengue virus

- The dengue virus can only replicate inside a host organism. It is a roughly spherical structure composed of the viral genome and capsid proteins surrounded by an envelope and a shell of proteins. The envelope is a lipid bilayer that is taken from the host. Embedded in the viral envelope are E and M proteins that span through the lipid bilayer. These proteins form a protective outer layer that controls the entry of the virus into human cells.
After infecting a host cell, the dengue virus hijacks the host cell's machinery to replicate the viral RNA genome and viral proteins. After maturing, the newly synthesized dengue viruses are released and go on to infect other host cells[23].

Summary:

1. Dengue is one of the most lethal disease.
2. Around 2.5 to 3.9 billion people worldwide are at risk of dengue infection.
3. 390 million dengue infections per year.
4. Increased number of 3.2 million dengue cases reported in 2015 as compared to 2.2 million in 2010.

3. What causes Dengue?

Answer: *Aedes aegypti* mosquito is the primary vector of the dengue virus. The virus is transmitted to humans through the bites of female mosquitoes.

Vector-borne diseases like dengue are the illnesses caused by parasites and pathogens in human populations. 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.



(a) *Aedes Aegypti*



(b) *Aedes Albopictus*

Figure 3: Dengue vectors

Aedes albopictus also called as *Asian tiger mosquito*, is a secondary dengue vector in Asia, has spread to North America and more than 25 countries in the European Region, largely due to the international trade in used tyres (a breeding habitat) and other goods (e.g. lucky bamboo). *Ae. albopictus* is highly adaptive and, therefore, can survive in cooler temperate regions of Europe. Its spread is due to its tolerance to temperatures below freezing, hibernation, and ability to shelter in microhabitats.

Summary:

1. Two types of mosquitoes from same genus namely, *Aedes aegypti* and *Aedes albopictus* carry dengue virus from an infected person to another uninfected person.
2. These mosquitoes transmit dengue virus by injecting virus into the uninfected person's body through saliva during their blood meal.

4. How does a mosquito carry a dengue virus?

Answer:

1. 'Typically, both male and female mosquitoes feed on nectar and plant juices. But in many species, to lay eggs, female mosquito needs to obtain protein from a blood meal. For this, in many species the mouthparts of the females are adapted for piercing the skin of animal hosts and sucking their blood[7].'
2. 'The mosquito becomes infective approximately seven days after it has bitten a person carrying the virus. This is the extrinsic incubation period, during which time the virus replicates in the mosquito and reaches the salivary glands[8].'
3. 'Mosquitoes carrying such arboviruses(any virus that is transmitted by an arthropod.) stay healthy because their immune systems recognizes the virions as foreign particles and "chop off" the virus's genetic coding, rendering it inert. Human infection with a mosquito-borne virus occurs when a female mosquito bites someone while its immune system is still in the process of destroying the virus's harmful coding.
It is not completely known how mosquitoes handle eukaryotic parasites to carry them without being harmed. Data has shown that the malaria parasite *Plasmodium falciparum* alters the mosquito vector's feeding behaviour by increasing frequency of biting in infected mosquitoes, thus increasing the chance of transmitting the parasite[7].'

Summary:

1. Only female mosquitoes need protein in the blood for laying eggs. Hence, only female mosquitoes carry dengue virus from infected person during their blood meal.
2. These mosquitoes become infective approximately seven days after their infected blood meal. During this incubation period virus replicates in the mosquitoes and reaches the salivary glands.
3. Mosquitoes carrying these viruses are immune to those foreign particles.

5. How do mosquitoes transmit dengue to a person?

Answer:

'Once an infected mosquito has incubated the virus for 4–10 days, it can transmit the virus for the rest of its life[5].'

'Prior to and during blood feeding, blood-sucking mosquitoes inject saliva into the bodies of their source(s) of blood. This saliva serves as an anticoagulant and the main route by which mosquito physiology offers passenger pathogens access to the hosts' interior. The salivary glands are a major target to most pathogens, whence they find their way into the host via the stream of saliva[7].'

Interesting facts about mosquito feed and hunt for blood hosts:

1. 'All adult mosquitoes feed on the nectar or honey dew of plants to get sugar, and that provides enough nourishment for both males and females to live. Both plant materials and blood are useful sources of energy in the form of sugars, and blood also supplies more concentrated nutrients, such as lipids, but the most important function of blood meals is to obtain proteins as materials for egg production.
2. A mosquito has a variety of ways of finding its prey, including chemical, visual, and heat sensors.
3. **Feeding preferences of mosquitoes:** Those with type O blood, heavy breathers, those with a lot of skin bacteria, people with a lot of body heat, and the pregnant.
4. When a female reproduces with such parasitic meals, this reproduction is termed as **anautogenous** ('anautogeny' is the condition found in many insects, where a gravid female has to feed before laying eggs in order for the eggs to mature.), as occurs in mosquito species that serve as disease vectors, particularly Anopheles and **Aedes**.
5. **Hunting for host location:** female mosquitoes hunt their blood host by detecting organic substances such as carbon dioxide (CO₂) and 1-octen-3-ol (octenol for short and also known as mushroom alcohol, is a chemical that attracts biting insects such as mosquitoes.) produced from the host, and through optical recognition. Mosquitoes prefer some people over others. The preferred victim's sweat simply smells better than others' because of the proportions of the carbon dioxide, octenol and other compounds that make up body odor.
Another compound identified in human blood that attracts mosquitoes is sulcatone or 6-methyl-5-hepten-2-one, especially for **Aedes aegypti** mosquitoes with the odor receptor gene Or4.
A large part of the mosquito's sense of smell, or olfactory system, is devoted to sniffing out blood sources. Of 72 types of odor receptors on its antennae, at least 27 are tuned to detect chemicals found in perspiration.
In **Aedes**, the search for a host takes place in two phases. First, the mosquito exhibits a nonspecific searching behavior until the perception of host stimulants, then it follows a targeted approach[7].'

6. Both dengue vectors *Ae. aegypti* and *Ae. Albopictus* are daytime feeders: The peak biting periods are early in the morning and in the evening before dusk.



(a) Mosquito before feeding.



(b) Mosquito after feeding.

Figure 4: Mosquito before and after feeding.

Summary:

1. Once the mosquito has incubated the dengue virus, it can transmit the virus for rest of its life.
2. During the blood meal on uninfected person's body, mosquito carrying dengue virus injects saliva into the person's body. This saliva serves the main route by which pathogens find their way into the host's interior.
3. **Feeding preferences:** Those with type O blood, heavy breathers, those with a lot of skin bacteria, people with a lot of body heat, and the pregnant.
4. **Hunting for host location:** By detecting organic substances like carbon dioxide, octenol, and sulcatone produced from the host and through optical recognition.
5. Peak biting period of dengue vector mosquitoes is daylight; approximately two hours after sunrise and several hours before sunset.

6. What is the life cycle of Aedes Aegypti?

Answer:

Aedes Aegypti is a so-called holometabolous insect. This means that the insects goes through a complete metamorphosis with an egg, larvae, pupae, and adult stage. The life cycle of Aedes aegypti can be completed within one-and-a-half to three weeks.

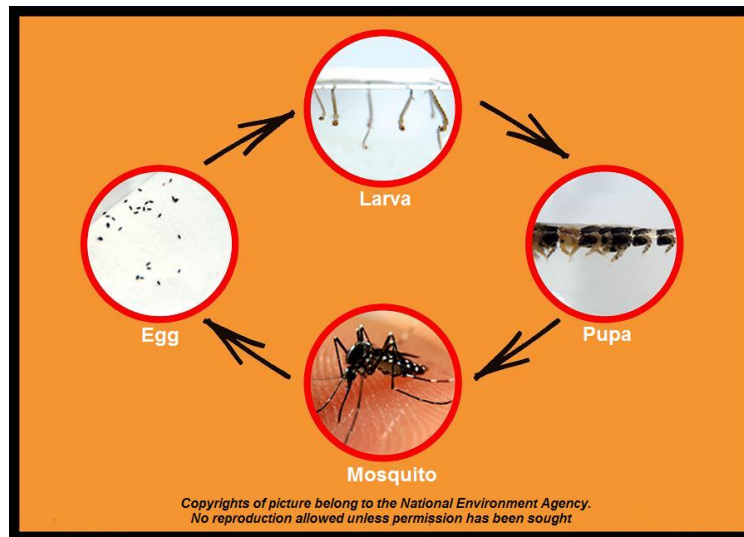


Figure 5: Mosquito life cycle[10].

1. **Egg:** After taking a blood meal, female Aedes aegypti mosquitos produce on average 100 to 200 eggs per batch. The females can produce up to five batches of eggs during a lifetime.

Eggs are laid on damp surfaces in areas likely to temporarily flood, such as tree holes and man-made containers and a lot more places where rain-water collects or is stored.

The female Aedes aegypti lays her eggs separately unlike most species. Not all eggs are laid at once, but they can be spread out over hours or days, depending on the availability of suitable substrates. Eggs will most often be placed at varying distances above the water line. The female mosquito will not lay the entire clutch at a single site, but rather spread out the eggs over several sites.

The eggs of Aedes aegypti are smooth, long, ovoid shaped, and roughly one millimeter long. When first laid, eggs appear white but within minutes turn a shiny black. In warm climates eggs may develop in as little as two days, whereas in cooler temperate climates, development can take up to a week. Laid eggs can survive for very long periods in a dry state, often for more than a year. However, they hatch immediately once submerged in water. This makes the control of the dengue virus mosquito very difficult.

2. **Larvae:** After hatching of the eggs, the larvae feed on organic particulate matter in the water, such as algae and other microscopic organisms. Most of the larval stage is spent at the water's surface. Larvae are often found around the home in puddles, tires, or within any object holding water.

Larval development is temperature dependent. Males develop faster than females, so males generally pupate earlier. If temperatures are cool, Aedes aegypti can remain in the

larval stage for months so long as the water supply is sufficient.

The larvae pass through four instars, spending a short amount of time in the first three, and up to three days in the fourth instar. Fourth instar larvae are approximately eight millimeters long. Males develop faster than females, so males generally pupate earlier. If temperatures are cool, *Aedes aegypti* can remain in the larval stage for months so long as the water supply is sufficient.



(a) *Ae. aegypti* larvae stage



(b) *Ae. aegypti* pupae stage.

Figure 6: *Aedes aegypti* larvae and pupae stage.

7. **Pupae:** After the fourth instar, the larvae enters the pupal stage. Mosquito pupae are mobile and respond to stimuli. Pupae do not feed and take approximately two days to develop. Adults emerge by ingesting air to expand the abdomen thus splitting open the pupal case and emerge head first[11].
8. Adult mosquitoes usually mate within a few days after emerging from the pupal stage. In most species, the males form large swarms, usually around dusk, and the females fly into the swarms to mate. Males typically live for about 5–7 days, feeding on nectar and other sources of sugar. After obtaining a full blood meal, the female will rest for a few days while the blood is digested and eggs are developed. This process depends on the temperature, but usually takes two to three days in tropical conditions. Once the eggs are fully developed, the female lays them and resumes host-seeking.

Summary:

1. *Aedes Aegypti* goes through a complete metamorphosis with an egg, larvae, pupae, and adult stage.
2. After a blood meal, female *Ae. aegypti* mosquitoes lay up to five batches of 100 to 200 eggs. The eggs are laid on damp surface areas over several sites. The eggs can lie dormant in dry conditions for up to about nine months, after which they can hatch if exposed to favourable conditions, i.e. water and food[10].
3. Larval stage is temperature dependant. It passes through 4 instars. Males develop faster than females. If temperatures are cool, it remains in the larval stage for months as long as the water supply is sufficient.
4. Pupae do not feed and take approximately two days to develop into adult mosquito. The adult life span can range from two weeks to a month depending on environmental conditions.

9. What are the symptoms of dengue infection? What is the duration of mosquito bite to positive dengue condition? What are the intermediate stages of mosquito bite and positive dengue conditions?

Answer:

1. **'Incubation period:** (Time between mosquito's bite to onset of symptoms) After the infective bite, the dengue virus circulates in the blood. The incubation period for Dengue Fever and Dengue Haemorrhagic Fever lasts from 3 to 14 days. The average incubation period is 4-6 days.
2. **Symptoms of dengue infection:** The signs and symptoms of dengue fever vary according to the age of the patient. The principal symptoms of dengue are high fever, severe headache, backache, joint pains, nausea and vomiting, eye pain and rash. Infants and young children may have a fever and a rash. They have milder illness compared to other older children and adults[12].
Thereafter symptoms appear such as a high fever (40°C/104°F) accompanied by 2 of the following symptoms: severe headache, pain behind the eyes, muscle and joint pains, nausea, vomiting, swollen glands or rash. These symptoms usually last for 2-7 days[5].
3. **Dengue Haemorrhagic Fever (DHF) and Dengue Shock Syndrome (DSS):** These are characterised by a sudden onset of fever, as high as 40-41°C, lasting about 2-7 days with similar signs and symptoms of dengue fever. This is followed by "leaky" capillaries allowing fluid component to escape from the blood vessels causing shock and hemorrhagic manifestations such as bleeding nose or gums, and possibly internal bleeding. Platelet counts will fall to less than 100,000/mm³. The course of DHF is 7-10 days.
During the acute phase of dengue, it is difficult to distinguish DHF/DSS from Dengue fever and other viral illnesses. The critical stage of DHF/DSS occurs most frequently from 24 hours after the temperature falls to or below normal. If Dengue Haemorrhagic Fever is not treated, it can lead to Dengue Shock Syndrome.

Summary:

1. After the infective bite, the average incubation period of dengue virus is 3-6 days.
2. The principal symptoms of dengue are high fever, severe headache, backache, joint pains, nausea and vomiting, eye pain and rash.
3. Severe dengue or Dengue Haemorrhagic Fever (DHF) is a potentially deadly complication due to plasma leaking, fluid accumulation, respiratory distress, severe bleeding, or organ impairment.

10. **Which conditions are favourable for dengue mosquito breeding?**

Answer:

1. ' *Aedes aegypti* originated from Africa, is now present globally in tropical and sub-tropical regions (see also Epidemiology). The mosquito has a so-called cosmo-tropical distribution annually, and spreads to more temperate regions during the summer. Living near man *Aedes aegypti* has become largely dependent on and adapted to humans. For instance, the mosquito has greatly reduced the 'humming' sound it makes with their wings. Humans nearly hear *Aedes aegypti*, unlike other species whose humming is extremely irritating and awakens the deepest sleeper. The insect is very fast in flight unless gorged with blood. Other types of mosquito even fly into your face and can be easily caught or killed, not *Aedes aegypti*.

2. *Aedes aegypti* is adapted to breed around human dwellings and prefers to lay its eggs in clean water which contains no other living species.

The mosquito *Aedes aegypti* comes in three polytypic forms: domestic, sylvan, and peridomestic.

- The domestic form breeds in urban habitat, often around or inside houses.
- The sylvan form is a more rural form, and breeds in tree holes, generally in forests.
- The peridomestic form thrives in environmentally modified areas such as coconut groves and farms.

3. Mosquitoes prefer stagnant water within which to lay their eggs. They most commonly infest ponds, marshes, swamps and other wetland habitats. However, they are capable of thriving in a variety of locations and can successfully grow in numbers even when not in their natural habitat. Many species of mosquitoes use containers of water as egg-deposit sites. Hot, humid environments are most amenable to mosquito growth and survival. Infestations can occur easily in tropical areas.

The *aedes* mosquito goes into hibernation when the temperature dips. The favourable condition for mosquito breeding is a humidity level of 60% and an atmospheric temperature between 21 and 23 degrees celsius[15].'

Mosquito larvae can be found in various habitats. Some larvae are active in transient waters such as floodwater, ditches and woodland pools. The *Anopheles*, *Culex*, *Culiseta*, *Coquillettidia* and *Uranotaenia* species breed in permanent bodies of water and can survive in polluted water as well as freshwater, acid water and brackish water swamps. Other mosquito larvae may be present in container water sources such as puddles upon leaves and stagnant water within small pools.

4. **Relationship Between Mosquitoes and Water**

'Mosquitoes live in water but must make periodic trips to the water's surface in order to eliminate carbon dioxide and inhale a fresh supply of oxygen.

Water provides mosquitoes with a place to lay eggs, grow and develop through their water stages (egg, larval and pupal). After the airborne portion of their lifecycle, females return to water to lay a new batch of fertile eggs. Female mosquitoes usually lay their

eggs on the surface of water or in areas where water can rise, flood the eggs, and stimulate them to hatch. Even as adult mosquitoes leave the pupal stage and become adults, water still plays a role because adult mosquitoes exit the pupal case on the water's surface and "dry out" before taking flight[14].'

5. National Environmental Agency, Singapore has listed following places at potential sites for mosquito breeding[8].

Usual mosquito breeding sites:

1. Flower pot and flower pot plates.
2. Hardened soil of potted plants .
3. Corner of the toilet bowl.
4. Gully trap.
5. Roof gutter.
6. Roadside drain.
7. Scuppar drain.

Unusual mosquito breeding sites:

1. Tree hole.
2. Plant axil.
3. Aircon-tray.
4. BBQ pit.
5. Canvas sheets.
6. Discarded receptacles
7. Planted box.

Table 1:Top 5 breeding habitats of Aedes Aegypti.

Top 5 breeding habitats of Aedes Aegypti	
Breeding habitats in homes	Breeding habitats in public places
1. Domestic Containers	1. Closed Perimeter Drains
2. Flower Pot Plates / Trays	2. Discarded Receptacles
3. Ornamental Containers	3. Gully Traps
4. Plants (Hardened Soil and Plant Axils)	4. Opened Perimeter Drains
5. Toilet Bowl / Cistern	5. HDB Corridor Scupper / Gullies

11. What are the preventive measures that can be implemented in order to avoid creating possible mosquito breeding site?

Answer:

As per the WHO recommendation, the main method to control or prevent the transmission of dengue virus is to combat vector mosquitoes through:

Preventing mosquitoes from accessing egg-laying habitats by environmental management and modification.

Disposing of solid waste properly and removing artificial man-made habitats.

Covering, emptying and cleaning of domestic water storage containers on a weekly basis.

Applying appropriate insecticides to water storage outdoor containers.

Using of personal household protection such as window screens, long-sleeved clothes, insecticide treated materials, coils and vaporizers.

Improving community participation and mobilization for sustained vector control.

Applying insecticides as space spraying during outbreaks as one of the emergency vector-control measures.

Active monitoring and surveillance of vectors should be carried out to determine effectiveness of control interventions.

12. **Is it possible to make dengue mosquitoes harmless at any stage of their life cycle before they spread virus? If yes, what are the possible ways?**

Answer: Wolbachia-Aedes Mosquito Suppression Strategy.

NEA's Environmental Health Institute (EHI) has studied various novel mosquito control methods over the past six years, and has focused on the Wolbachia method over the last four years. Wolbachia's potential to reduce the *Aedes aegypti* mosquito population has been demonstrated in our laboratories[27].

Wolbachia technology is considered a biological control method. Wolbachia are naturally occurring bacteria found in more than 60 per cent of insects around us, including butterflies, dragonflies, fruit flies, and various mosquito species such as *Aedes albopictus*, but not in the primary dengue vector mosquito *Aedes aegypti*. Wolbachia have not been shown to infect humans or other mammals, even when carried by biting insects.

The World Health Organization (WHO) Vector Control Advisory Group (VCAG) recommends carefully planned pilot deployment under operational conditions accompanied by rigorous independent monitoring and evaluation that builds entomological capacity to support operational use, for the use of Wolbachia against Aedes-borne diseases.

The Dengue Expert Advisory Panel (DEAP), comprising experts from Singapore, Australia, the United Kingdom (UK) and the United States of America (USA), recommends that Singapore explores the use of Wolbachia-carrying *Aedes* males to help suppress the *Aedes* mosquito population in Singapore, for further reduction of the risk of dengue[26].

How does Wolbachia-Aedes suppression strategy works?

1. When male Wolbachia-carrying *Aedes aegypti* mosquitoes mate with female *Aedes aegypti* without Wolbachia, their resulting eggs do not hatch. This is because such matings are biologically incompatible. Thus release of male Wolbachia-*Aedes aegypti* will lead to a decline in the *Aedes aegypti* population in the field over time.
2. The outcome of this approach is consistent with our current emphasis on source reduction (removal of breeding habitats).
3. This mosquito suppression strategy is species-specific. Release of male Wolbachia-*Aedes aegypti* will only impact the *Aedes aegypti* population in the field, and not other insects [28].

Dengue numbers in Singapore.

The incidence of dengue in Singapore exhibits a distinct seasonality. It typically rises in the warmer months. Usually starting from April, the incidence reaches a peak in July or August, and declines in September or October[16]. WHO report mention that in Asia, Singapore has reported an increase in cases after a lapse of several years[5].

13. How many positive dengue cases are recorded in each district of Singapore?

Answer:

1. In Singapore, there are around 4,000 to 5,000 reported cases of dengue or dengue haemorrhagic fever every year. Since 1980s, more than 50% of deaths in the country have occurred in adults (individuals older than 15 years)[25]. 'MOH-NEA's quarterly dengue surveillance data mentions following information:

2. No. of cases reported:

- (a) Jul to Sept 2016 (03/07/2016 - 1/10/2016), = 2,888 dengue cases (4 DHF cases); an increase of 2.7% as compared to the previous quarter from April to Jun 2016.
- (b) Oct to Dec 2016 (02/10/2016 - 31/12/2016), = 1084 dengue cases (1 DHF cases); a decrease of 62.5% as compared to the previous quarter from Jul to Sep 2016.
In 2016 (03/01/2016-31/12/2016), a cumulative total of **13,115** dengue cases were notified to Ministry of Health (MOH).

3. No. of deaths:

- (a) Jan to Jun 2016 : 6
- (b) Jul to Sept 2016 : 2
- (c) Oct to Dec 2016 : 1

This brings the annual number of deaths in the year 2016 to 9[19].'

4. **Serotype Distribution:** Preliminary results of the positive dengue samples serotyped in Jul to Dec 2016 have indicated that DEN-1 accounted for majority of the typed samples, followed by DEN-2, DEN-3 and DEN-4.

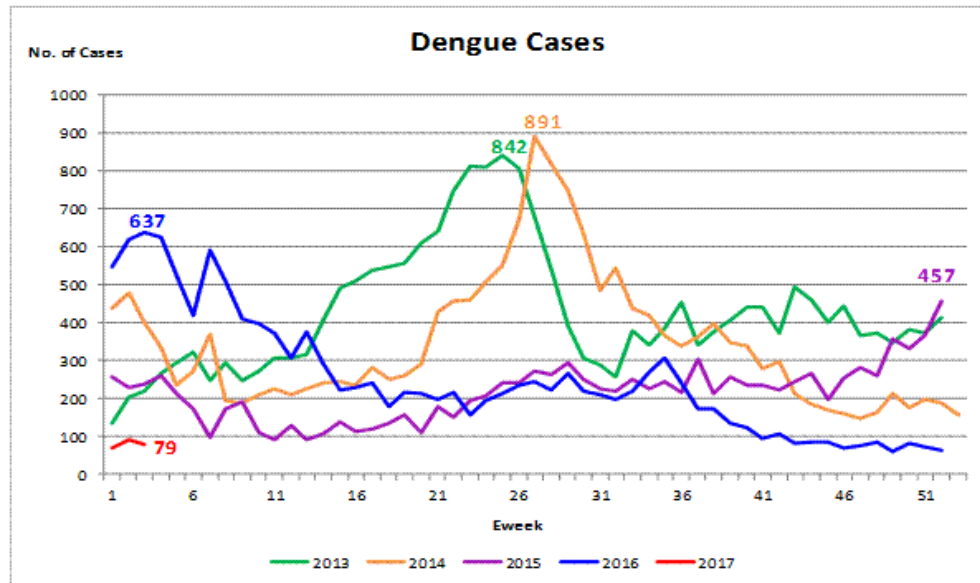


Figure 7: Dengue Cases(Year 2013-2016)[21].

Number of Dengue cases						
<i>It is important to note that day-to-day numbers fluctuates as they depend on the number of notification received. Therefore, weekly numbers are a better reflection of actual trends.</i>						
No. of Reported Cases*						
19-Jan	20-Jan	21-Jan	22-Jan	23-Jan	24-Jan	25-Jan at 3pm
14	10	11	7	14	16	5
*provisional						
No. of Reported Cases by E-week (from Sun 0000hrs to Sat 2359hrs)						
E-week 50 (11-17Dec16)	E-week 51 (18-24Dec16)	E-week 52 (25-31Dec16)	E-week 01 (01-07Jan17)	E-week 02 (08-14Jan17)	E-week 03 (15-21Jan17)	E-week 04 (22-25Jan17 at 3pm)
81	72	64	70	91	79	42
Cumulative No. of cases for 2017 (First 3 weeks): 240						
Compiled by Communicable Diseases Division, Ministry of Health						

Figure 8: Dengue Cases reported by E-week[21].

14. Which are the dengue clusters in Singapore?

Answers:

1. Operationally, a dengue cluster indicates a locality with active transmission where intervention is targeted. It is formed when two or more cases have onset within 14 days and are located within 150m of each other (based on residential and workplace addresses as well as movement history). The clusters are categorised according to their current status. There are 3 alert levels:

Definition	Alert Level
High-risk area with 10 or more cases	Red
High-risk area with less than 10 cases	Yellow
No new cases, under surveillance for the next 21 days	Green

Figure 9: Categories of dengue clusters[17].

2. Following map shows the high-risk dengue clusters in Singapore.

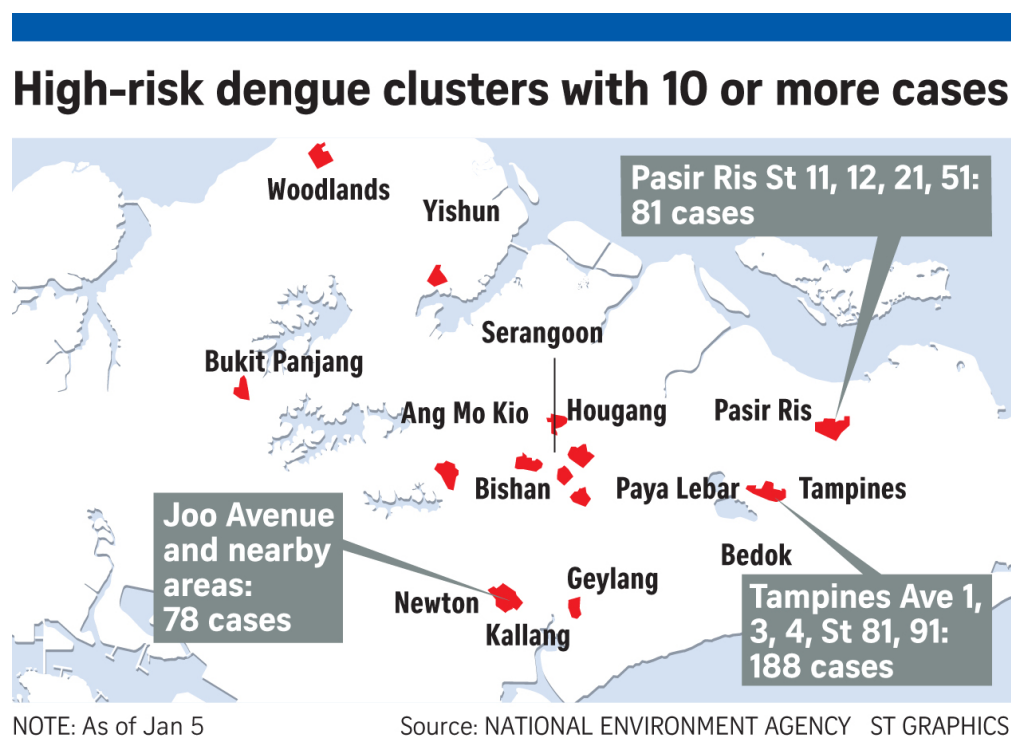


Figure 10: High-risk dengue clusters[18].

3. For 2016, about 17,000 mosquito breeding have been detected and destroyed. The breakdown of breeding found at various premises types are found in Table 2. The largest proportion of breeding is still being found in homes.

Table 2: No. of breeding detected from Jan to Dec 2016*

Mosquito habitats	2016
Residential premises	About 7,800 (46%)
Public areas About	4,900 (30%)
Construction sites	About 870 (5%)
Others About	3,200 (19%)
Total About	17,000

*Provisional; generated as of 9 Jan 2017.

More about Dengue clusters in Singapore:

1. Dengue Clusters 1990 to 2015.

Dengue clusters identified, 1990 – 2015						
Year	No. of indigenous cases	No. of clusters*	No. of cases in cluster area (% total cases)	No. of clusters with >=10 cases (% total clusters)	Median no. of cases per cluster	Median duration of transmission (days)
1990	1,640	40	270 (16.5)	11 (27.5)	4.5	10
1991	2,062	74	414 (20.1)	9 (12.2)	3.5	6
1992	2,741	134	733 (26.7)	13 (9.7)	3	5
1993	794	33	183 (23.0)	4 (12.1)	3	8
1994	1,084	75	424 (39.1)	8 (10.7)	3	7
1995	1,756	118	679 (38.7)	16 (13.6)	3	7
1996	2,877	143	1,088 (37.8)	27 (18.9)	3	6
1997	4,039	198	1,124 (27.8)	24 (12.1)	3	5
1998	5,105	239	1,197 (23.4)	23 (9.6)	2	7
1999	1,138	54	230 (20.2)	6 (11.1)	3	11
2000	402	9	40 (10.0)	1 (11.1)	4	15
2001	2,064	93	531 (25.7)	15 (16.1)	3	8
2002	3,560	73	725 (20.4)	30 (41.1)	7	20
2003	4,542	180	1,405 (30.9)	38 (21.1)	4.5	12
2004	9,297	559	2,434 (26.2)	34 (6.1)	3	4
2005	14,032	1,190	5,362 (37.7)	93 (7.8)	3	5
2006	2,844	172	871 (30.6)	19 (11.0)	3	5
2007	8,287	949	3,877 (46.8)	58 (6.1)	3	10
2008	6,631	576	2,267 (34.2)	34 (5.9)	2	7
2009	4,187	392	1,456 (34.8)	17 (4.3)	3	7
2010	4,978	406	1,858 (37.3)	29 (7.1)	3	7
2011	5,099	433	1,904 (37.3)	32 (7.4)	3	7
2012	4,369	328	1,403 (30.9)	21 (6.4)	3	6
2013	21,863	1,475	10,256(46.3)	188 (12.7)	3	9
2014	17,812	1,418	9,474 (51.7)	137 (9.7)	3	9
2015	10,856	1,114	5,744 (50.9)	108 (9.7)	3	10

*A cluster is defined as two or more cases epidemiologically linked by place [within 150m (200m till 2002)] and time (within 14 days)

Figure 11: Dengue Clusters identified during 1990 to 2015[29].

2. Premises Percentage of Aedes breeding habitat.

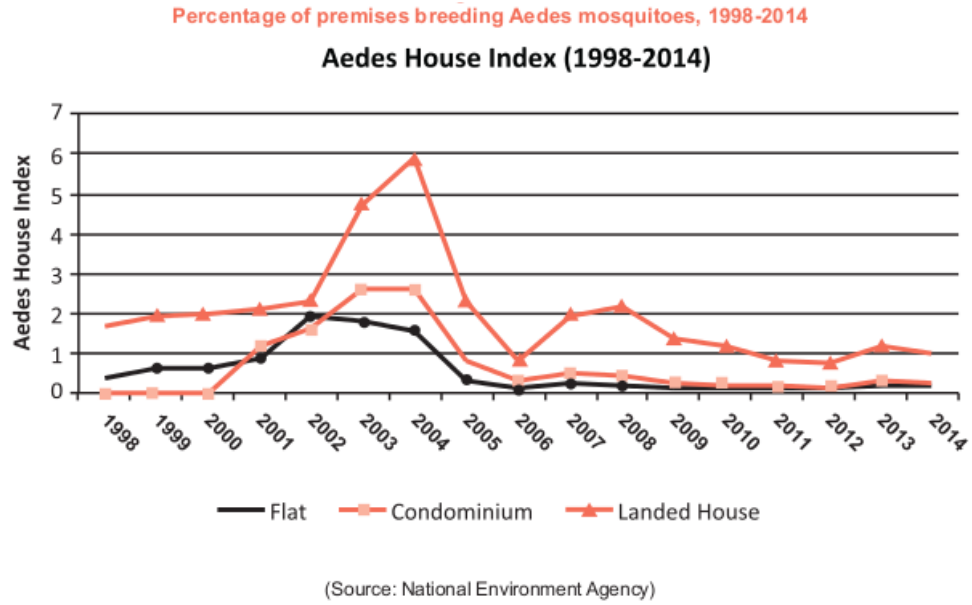


Figure 12: Percentage of Premises breeding of Aedes Mosquitoes from 1998 to 2014[30].

3. Dengue cases incidence rates by housing type.

Incidence rates of reported indigenous DF/DHF cases by housing type, 2000		
Housing types	Cases (%)	Incidence rates per 100,000 population*
Compound house	104 (25.9)	43.6
HDB flat	215 (53.5)	8.8
Condominium	42 (10.4)	21.6
Bangsals, containers/workers' quarters	41 (10.2)	45.0
Total	402 (100)	13.5
*Rates are based on 2000 census population (Source: Department of Statistics, Singapore)		

Figure 13: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2000[44].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2001		
Housing types	Cases (%)	Incidence rates per 100,000 population*
Compound house	629 (30.5)	275.4
HDB flat	1049 (50.8)	38.0
Condominium	181 (8.8)	135.3
Bangsals, containers/workers' quarters and others	205 (9.9)	146.1
Total	2064 (100.0)	63.3
*Rates are based on 2000 census population (Source: Department of Statistics, Singapore)		

Figure 14: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2001[43].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2002		
Housing types	Cases (%)	Incidence rates per 100,000 population*
Compound house	855 (24.0)	358.9
HDB flat	2042 (57.4)	84.0
Condominium	410 (11.5)	211.2
Bangsals, containers/workers' quarters and others	253 (7.1)	292.4
Total	3560(100)	119.2

*Rates are based on 2000 census population
(Source: Department of Statistics, Singapore)

Figure 15: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2002[42].

Incidence rates of reported indigenous DF/DHF cases (Singaporeans and Permanent Residents) by housing type, 2003			
Housing Types	Cases	%	Incidence rate per 100,000 population
Compound houses (including shophouses)	1124	31.9	633.7
HDB flats	1937	55.0	63.9
Condominiums	453	12.9	220.4
Bangsals, containers/workers' quarters and others	7	0.2	-
Total	3521	100.0	102.9

Figure 16: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2003[41].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2004			
Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	1,877	20.2	586.7
HDB Flats	5,951	64.0	192.3
Condominiums	846	9.1	292.6
Bangsals, containers/workers' quarters and others	623	6.7	116.1
Total	9,297	100.0	219.3

*Rates are based on census of population 2000.
(Source: Singapore Department of Statistics)

Figure 17: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2004[40].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2005

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	2,333	16.6	710.7
HDB Flats	10,545	75.2	332.1
Condominiums	860	6.1	289.8
Others	294	2.1	53.4
Total	14,032	100.0	322.5

*Rates are based on census of population 2000.
(Source: Singapore Department of Statistics)

Figure 18: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2005[39].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2006

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	578	20.3	170.9
HDB Flats	1,878	66.0	57.4
Condominiums	318	11.2	104.0
Others	70	2.5	12.3
Total	2,844	100.0	63.4

*Rates are based on census of population 2000.
(Source: Singapore Department of Statistics)

Figure 19: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2006[38].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2007

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	1,217	14.7	351.5
HDB Flats	5,242	63.2	156.5
Condominiums	1,420	17.2	453.8
Others	408	4.9	70.2
Total	8,287	100.0	180.6

*Rates are based on census of population 2000.
(Source: Singapore Department of Statistics)

Figure 20: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2007[37].

Incidence rates of reported indigenous[#] DF/DHF cases by housing type, 2008

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	1,363	20.5	373.3
HDB Flats	3,540	53.4	100.2
Condominiums	927	14.0	280.9
Others	801	12.1	130.7
Total	6,631	100.0	137.0

[#]Cases acquired locally among Singaporeans, permanent and temporary residents.

*Rates are based on 2008 estimated mid-year population.
(Source: Singapore Department of Statistics)

Figure 21: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2008[36].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2009

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	856	20.4	227.9
HDB Flats	2,830	67.6	77.8
Condominiums	410	9.8	120.6
Others	91	2.2	14.4
Total	4,187	100.0	83.9

*Rates are based on census of population 2000.
(Source: Singapore Department of Statistics)

Figure 22: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2009[35].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2010

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	1,614	32.4	484.9
HDB Flats	2,615	52.5	76.3
Condominiums	672	13.5	130.4
Others	77	1.5	232.6
Total	4,978	100	115.5

*Rates are based on census of population 2010.
(Source: Singapore Department of Statistics)

Figure 23: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2010[34].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2011

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	668	18.7	200.7
HDB Flats	2,514	70.3	73.3
Condominiums	381	10.6	73.9
Others	13	0.4	39.2
Total	3,576	100.0	83.0

*Rates are based on census of population 2010.
(Source: Singapore Department of Statistics)

Figure 24: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2011[33].

Incidence rates of reported indigenous DF/DHF cases by housing type for Singapore residents, 2012

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	533	18.6	160.1
HDB Flats	1,992	69.6	58.1
Condominiums	284	9.9	55.1
Others	52	1.8	156.7
Total	2,861	100.0	66.4

*Rates are based on census of population 2010.
(Source: Singapore Department of Statistics)

Figure 25: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2012[32].

**Incidence rates of reported indigenous DF/DHF cases by housing type
for Singapore residents, 2013**

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	568	6.3	6845.0
HDB Flats	11539	85.4	1222.5
Condominiums	1098	6.0	852.1
Others	309	2.3	476.1
Total	13514	100.0	1179.3

*Rates are based on census of population 2010.
(Source: Singapore Department of Statistics)

Figure 26: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2013[31].

**Incidence rates of reported indigenous DF/DHF cases by housing type
for Singapore residents, 2014**

Housing Type	No.	%	Incidence rate per 100,000 population*
HDB Flats	7,117	67.5	225.6
Landed Properties (including shophouses)	2,266	21.5	896.3
Condominiums and Other Apartments	1,139	10.8	267.4
Others	16	0.2	43.0
Total	10,538	100.0	272.2

*Rates are based on census of population 2014.
(Source: Singapore Department of Statistics)

Figure 27: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2014[30].

**Incidence rates of reported indigenous DF/DHF cases by housing type
for Singapore residents, 2015**

Housing Type	No.	%	Incidence rate per 100,000 population*
HDB Flats	6,914	63.7	218.6
Landed Properties (including shophouses)	1,688	15.6	672.3
Condominiums and Other Apartments	2,253	20.7	497.4
Total	10,855	100.0	185.3

*Rates are based on census of population 2015.
(Source: Singapore Department of Statistics)

Figure 28: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2015[29].

4. Geographical Distribution of DF/DHF Clusters from 2000 to 2015.

Geographical distribution of DF/DHF clusters in Singapore, 2000

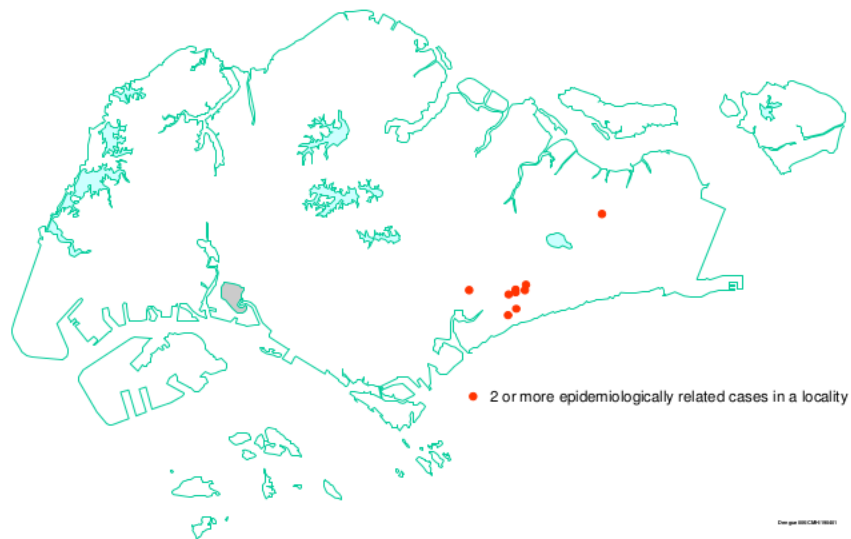


Figure 29: Geographical Distribution of DF/DHF Clusters in 2000[44].

Geographical distribution of DF/DHF clusters in Singapore, 2001

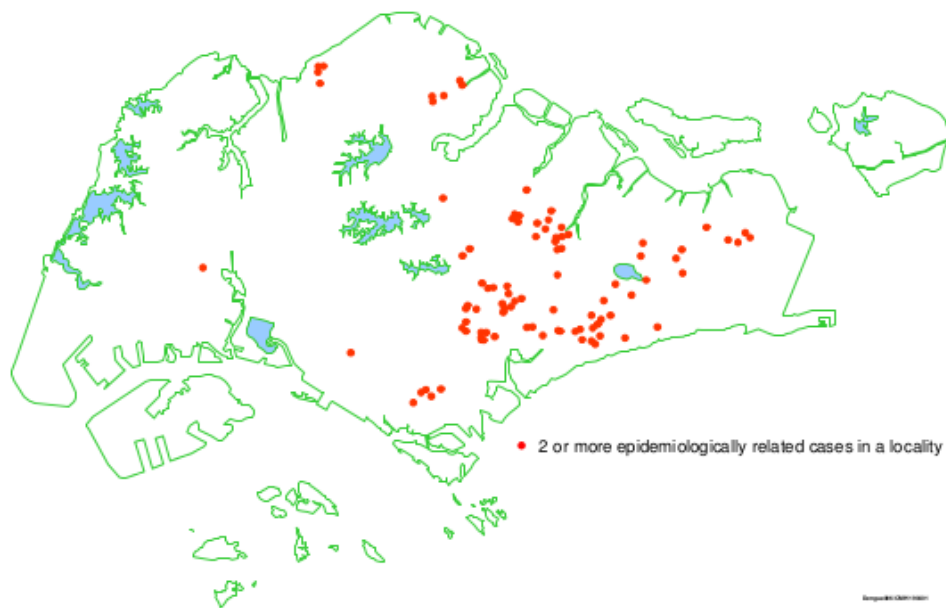


Figure 30: Geographical Distribution of DF/DHF Clusters in 2001[43].

Geographical distribution of DF/DHF clusters in Singapore, 2002

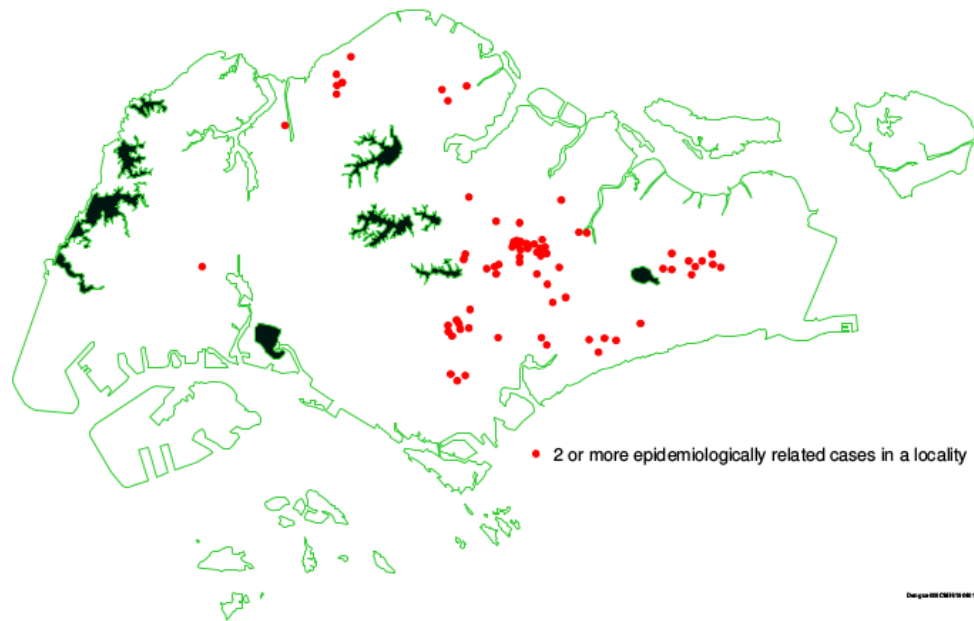


Figure 31: Geographical Distribution of DF/DHF Clusters in 2002[42].

5. Geographical Distribution of DF/DHF cases from 2003 to 2014.

Geographical distribution of DF/DHF clusters having 10 or more reported cases, 2003

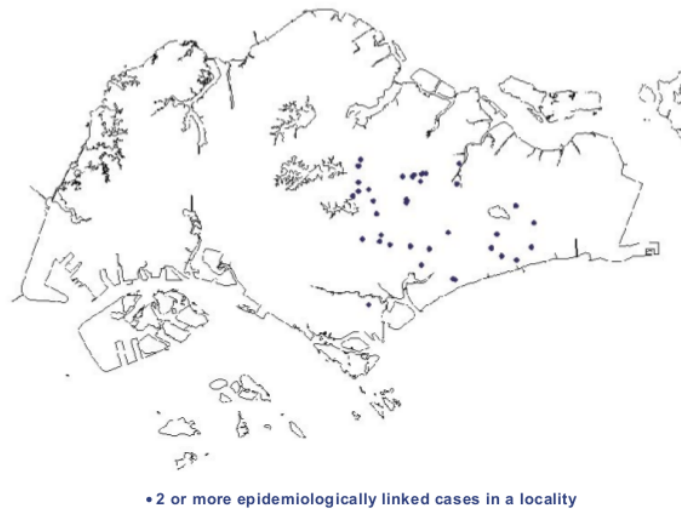


Figure 32: Geographical Distribution of DF/DHF cases in 2003[41].

Geographical distribution of dengue cases, 2004



Figure 33: Geographical Distribution of DF/DHF cases in 2004[40].

Geographical distribution of dengue cases in Singapore, 2005

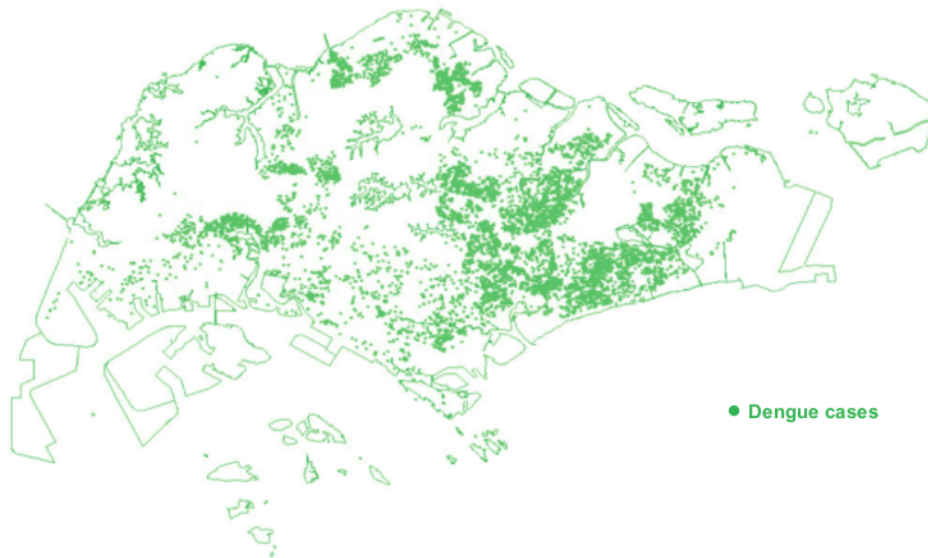


Figure 34: Geographical Distribution of DF/DHF cases in 2005[39].

Geographical distribution of dengue cases, 2006



Figure 35: Geographical Distribution of DF/DHF cases in 2006[38].

Geographical distribution of dengue cases, 2007

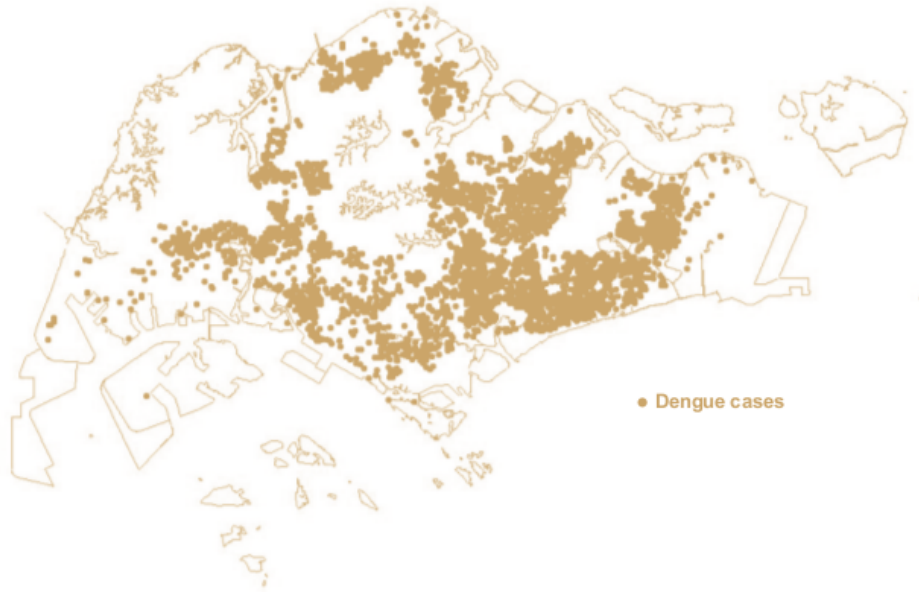


Figure 36: Geographical Distribution of DF/DHF cases in 2007[37].

Geographical distribution of dengue cases, 2008

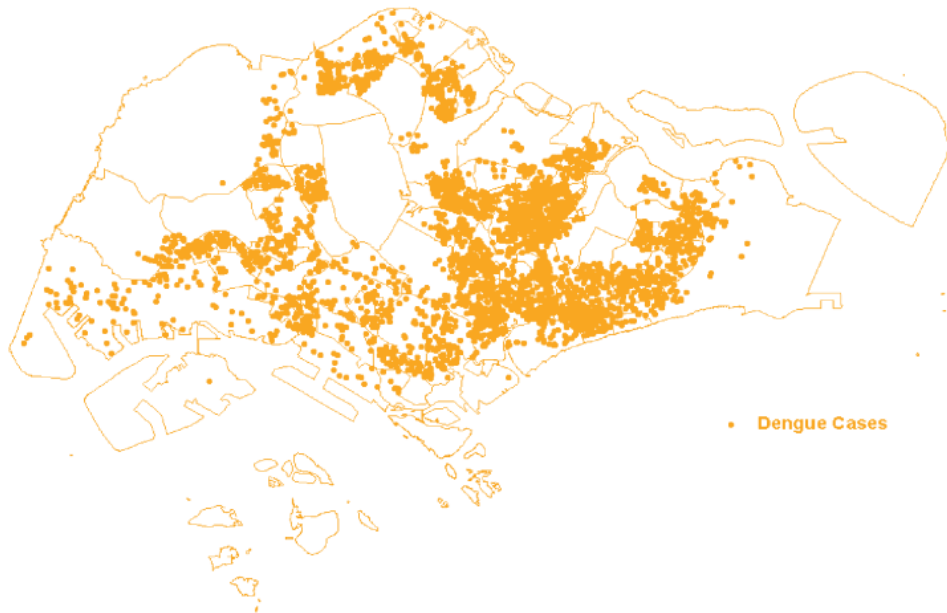


Figure 37: Geographical Distribution of DF/DHF cases in 2008[36].

Geographical distribution of dengue cases, 2009

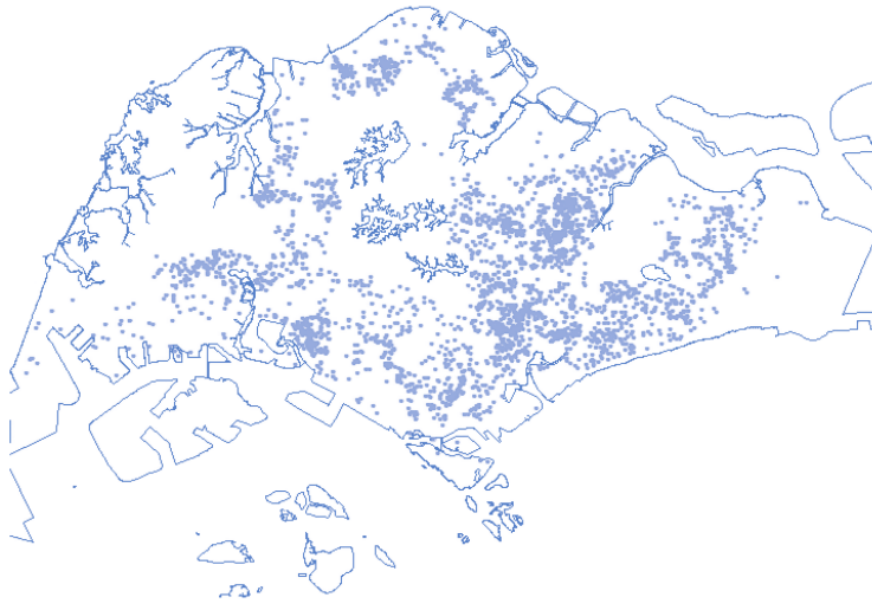


Figure 38: Geographical Distribution of DF/DHF cases in 2009[35].

Geographical distribution of dengue cases, 2010

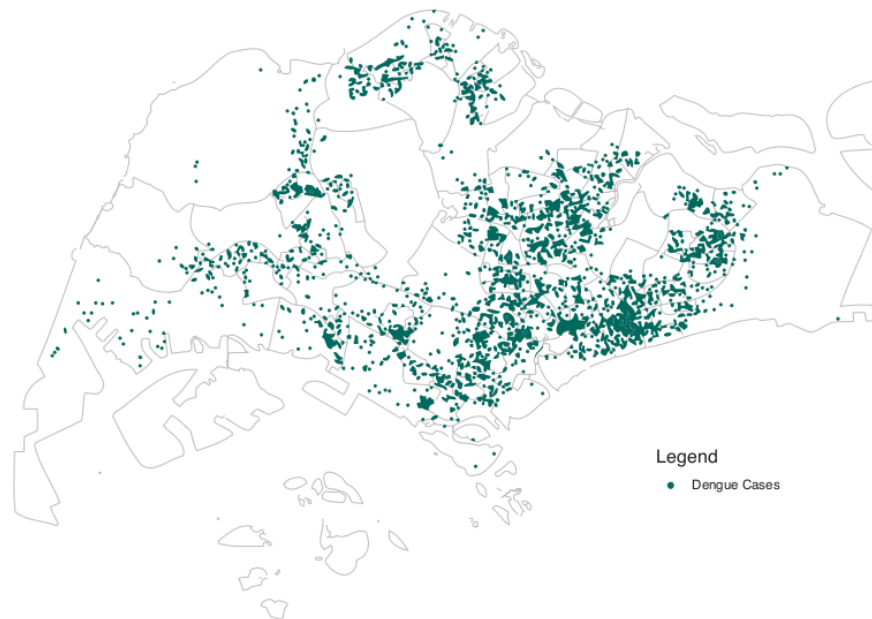


Figure 39: Geographical Distribution of DF/DHF cases in 2010[34].

Geographical distribution of dengue cases, 2011

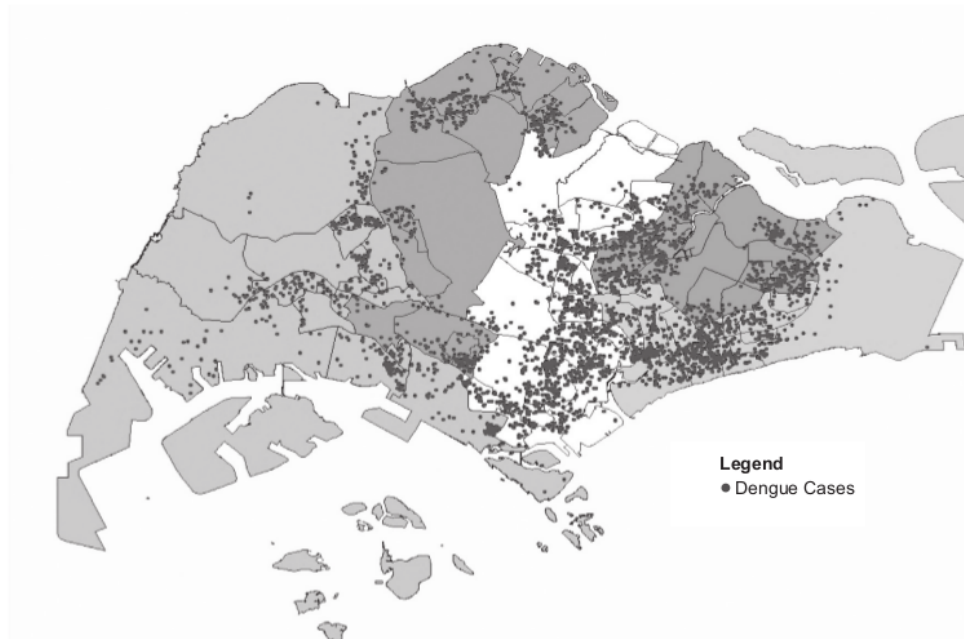


Figure 40: Geographical Distribution of DF/DHF cases in 2011[33].

Geographical distribution of DF/DHF cases, 2012

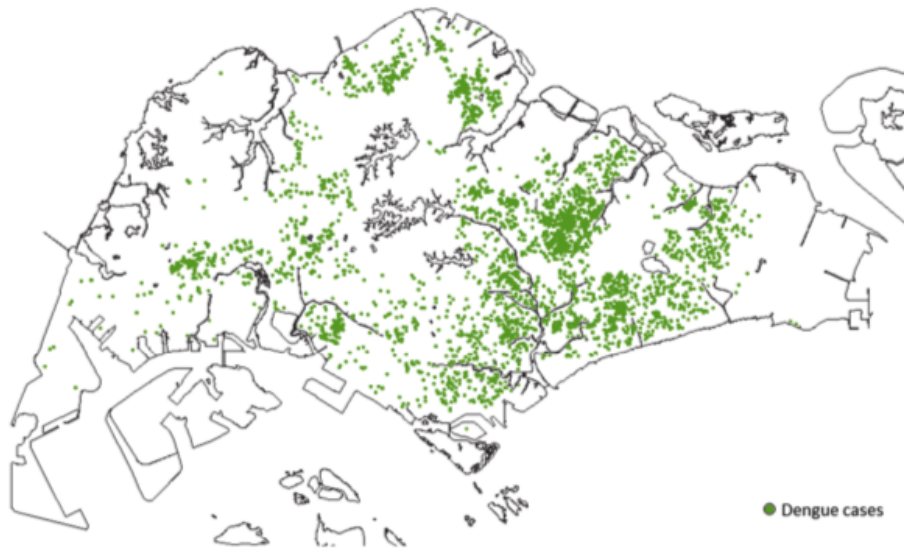


Figure 41: Geographical Distribution of DF/DHF cases in 2012[32].

Distribution of sentinel sites, 2013



(Source: National Environment Agency)

Figure 42: Sentinel Site Distribution in 2013[31].

Distribution of sentinel sites, 2014



(Source: National Environment Agency)

Figure 43: Sentinel site Distribution in 2014[30].

What are Sentinel sites?

World Health organization has defined surveillance systems in two categories.

- (a) Active surveillance system/ Sentinel surveillance system.
- (b) Passive surveillance system.

'Sentinel Surveillance system:

- A sentinel surveillance system is used when high-quality data are needed about a particular disease that cannot be obtained through a passive system. Selected reporting units, with a high probability of seeing cases of the disease in question, good laboratory facilities and experienced well-qualified staff, identify and notify on certain diseases.
- Data collected in a well-designed sentinel system can be used to signal trends, identify outbreaks and monitor the burden of disease in a community, providing a rapid, economical alternative to other surveillance methods.
- A sentinel system deliberately involves only a limited network of carefully selected reporting sites. For example, a network of large hospitals might be used to collect high-quality data on various diseases and their causative organisms, such as invasive bacterial disease caused by *Haemophilus influenzae* type b, meningococcus or pneumococcus.
- Because sentinel surveillance is conducted only in selected locations, however, it may not be as effective for detecting rare diseases or diseases that occur outside the catchment areas of the sentinel sites.

Passive surveillance system:

- Most passive surveillance systems receive data from as many health workers or health facilities as possible[45].'

6. Imported Dengue Cases.

Imported DF/DHF cases, 1996-2000					
	Year				
	1996	1997	1998	1999	2000
Southeast Asia					
Indonesia	113	103	51	116	171
Malaysia	99	107	66	65	64
Thailand	8	20	18	9	5
Philippines	4	4	1	1	3
Vietnam	1	2	1	2	0
Cambodia	0	5	3	2	2
Brunei	1	0	3	0	5
Myanmar	0	4	1	3	0
Laos	1	1	6	0	0
Indian subcontinent					
India	14	8	2	7	6
Bangladesh	2	0	0	4	9
Sri Lanka	4	0	0	6	3
Pakistan	1	0	0	0	0
Others					
China	2	0	0	0	0
Maldives Islands	0	0	0	1	1
Nigeria	0	0	0	0	1
Libya	0	0	1	1	1
Unknown	1	7	0	0	0
Total	251	261	153	217	271

Figure 44: Imported DF/DHF cases 1996 to 2000[44].

Imported DF/DHF cases, 2001 – 2005

	Year				
	2001	2002	2003	2004	2005
Southeast Asia					
Brunei	2	0	0	0	0
Cambodia	8	4	8	4	0
East Timor	1	0	0	0	0
Indonesia	142	155	93	17	11
Malaysia	77	139	100	22	2
Myanmar	8	2	1	1	0
Philippines	5	6	2	1	0
Thailand	32	43	18	3	1
Viet Nam	0	0	2	0	0
South Asia					
Bangladesh	8	3	1	1	0
India	19	14	14	7	0
Nepal	0	0	1	0	0
Pakistan	1	1	1	0	0
Sri Lanka	3	9	3	2	0
Other Regions	2	9	2	3	0
Total	308	385	246	61	14

Figure 45: Imported DF/DHF cases 2001 to 2005[39].

Imported DF/DHF cases, 2006 – 2010

	Year				
	2006	2007	2008	2009	2010
Southeast Asia					
Brunei	0	1	0	1	0
Cambodia	4	4	4	3	0
East Timor	0	1	1	1	1
Indonesia	34	34	40	19	42
Laos	1	0	0	1	0
Malaysia	25	31	42	32	34
Myanmar	0	4	1	1	0
Philippines	5	6	4	3	9
Thailand	8	14	15	2	11
Viet Nam	2	8	8	4	6
South Asia					
Bangladesh	5	2	2	0	0
India	12	20	13	9	26
Maldives	2	0	1	0	0
Nepal	0	0	0	1	0
Pakistan	0	0	0	0	0
Sri Lanka	1	2	1	0	1
Other Regions	4	12	11	6	6
Total	103	139	143	83	136

Figure 46: Imported DF/DHF cases 2006 to 2010[34].

Imported DF/DHF cases, 2011 – 2015

	Year				
	2011	2012	2013	2014	2015
Southeast Asia					
Brunei	1	0	1	1	0
Cambodia	8	11	2	1	1
East Timor	2	4	1	5	0
Indonesia	110	111	116	143	116
Laos	0	0	0	1	0
Malaysia	21	39	90	214	191
Myanmar	3	1	9	8	9
Philippines	12	13	10	17	26
Thailand	15	22	21	27	21
Vietnam	9	4	6	8	7
South Asia					
Bangladesh	13	5	4	6	6
China	1	3	12	9	2
India	16	32	17	39	35
Maldives	1	2	1	6	3
Nepal	0	0	0	1	0
Pakistan	2	0	1	0	1
Sri Lanka	5	4	1	6	2
Other Regions	12	12	15	22	18
Total	231	263	307	514	438

Figure 47: Imported DF/DHF cases 2011 to 2015[29].

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