# Training Module-1

## DDT and Vector Borne Diseases

**Developed under GEF Funded Project on**

**Development and Promotion of Non-POPs Alternatives to DDT**
(GEF Project ID: 4612)

**Training Programme on**
**Integrated Vector Pest Management (IVPM)**

**Executed by**
**Central Pollution Control Board (CPCB)**
**Ministry of Environment, Forest and Climate Change (MoEFCC)**

**Developed by**

**CSIR- National Environmental Engineering Research Institute, Nehru Marg,**
**Nagpur- 440 020, India**

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| | |
|---|---|
| **AES** | Acute Encephalitis Syndrome |
| **CCHF** | Crimean-Congo Haemorrhagic Fever |
| **CCHFV** | Crimean-Congo Haemorrhagic Fever Virus |
| **CDC** | Centers for Disease Control and Prevention |
| **CHIKV** | Chikungunya Virus |
| **CHPV** | Chandipura Virus |
| **DDD** | dichlorodiphenyldichloroethane |
| **DDE** | dichlorodiphenyldichloroethylene |
| **DDT** | Dichlorodiphenyltrichloroethane |
| **DENV** | Dengue Virus |
| **DF** | Dengue Fever |
| **DHF** | Dengue Hemorrhagic Fever |
| **EC** | Emulsifiable Concentrate |
| **GBS** | Guillain–Barré syndrome |
| **GoI** | Government of India |
| **HIL** | HIL (India) Limited |
| **ICMR** | Indian Council of Medical Research |
| **IDA** | Ivermectin, Diethylcarbamazine and Albendazole |
| **IRS** | Indoor Residual Spraying |
| **JE** | Japanese Encephalitis |
| **JEV** | Japanese Encephalitis Virus |
| **KFD** | Kyasanur Forest Disease |
| **KFDV** | Kyasanur Forest Disease Virus |
| **MDA** | Mass Drug Administration |
| **MoEFCC** | Ministry of Environment, Forest and Climate Change |
| **MT** | Metric Tonne |
| **NFME** | National Framework for Malaria Elimination |

| | |
|---|---|
| **Nm** | Nano meter |
| **NIP** | National Implementation Plan |
| **NIV** | National Institute of Virology |
| **NMCP** | National Malaria Control Programme |
| **NMEP** | National Malaria Eradication Programme |
| **NCVBDC** | National Centre for Vector Borne Disease Control |
| **NVBDCP** | National Vector Borne Disease Control Programme |
| **PAHO** | Pan American Health Organization |
| ***Pf*** | *Plasmodium falciparum* |
| ***Pv*** | *Plasmodium vivax* |
| **PKDL** | Post Kala-Azar Dermal Leishmaniasis |
| **POPs** | Persistent Organic Pollutants |
| **RNA** | Ribonucleic Acid |
| **SC POPs** | Stockholm Convention on Persistent Organic Pollutants |
| **TDR** | Tropical Disease Research |
| **UNEP** | United Nations Environment Programme |
| **USEPA** | United States Environmental Protection Agency |
| **UTs** | Union Territories |
| **WDP** | Water Dispersible Powder |
| **WHO** | World Health Organization |
| **WP** | Wettable Powder |
| **ZIKV** | Zika Virus |

# 1. Introduction to DDT and Persistent Organic Pollutants (POPs)

**Learning Objectives**

By the end of this training programme, participants should be able to

- Describe DDT and its uses
- Know what are Persistent Organic Pollutants and its' importance
- Describe Stockholm Convention on POPs and its Operation mechanism
- Describe the status of DDT in India and DDT supply in different States
- Brief about Global alliance for DDT and Alternatives to DDT

## 1.1. Introduction

Dichlorodiphenyltrichloroethane (DDT) is an organochlorine pesticide first synthesized in 1874 by the Austrian chemist Othmar Zeidler. However, its insecticidal property was discovered only in 1939 by Muller for which he was awarded Nobel Prize. The chemical structure of DDT permits several isomers, amongst, the ortho, para-DDT (o,p'-DDT), and para, para-DDT (p,p'- DDT), are the important isomers. However, the insecticidal property is predominantly due to p,p-DDT isomer. Commercially, the term DDT is used for products consisting predominantly of p,p'- DDT, but, other isomers of DDT such as o,p-DDT, and their degradation products such as p,p'- and o,p'-DDD (dichlorodiphenyldichloroethane) and p,p' and o,p'-DDE (dichlorodiphenyldichloroethylene) may also be present in appreciable quantities (about 20-25 %). For public health purpose, DDT is formulated as "technical grade" (should contain a minimum of 70 % p,p′-DDT) as per the specification of the World Health Organization (WHO, 2009). Typically, technical grade DDT also contains smaller amounts of other compounds such as o,p′-DDT (15-21 %), p,p′-DDD (also known as p,p′-TDE, 4 %) and o,p′-DDE (WHO, 2009). The other isomeric forms and the degradation products of DDT may add to the insecticidal action of "technical grade" DDT (Muller, 1948). For public health purposes, DDT is formulated in several different forms such as aerosols, dustable powders, emulsifiable concentrates, granules and wettable powders. Globally, DDT was widely used in agriculture to control pests during 1940-1970s. During this time, the environmental and ecotoxicological effects of DDT have been reported and several countries especially, USA and Europe have restricted/banned the use of DDT in agriculture (Rogan and Chen, 2005).

DDT was initially used by the United States military in World War-II to control malaria, typhus, body lice, and bubonic plague. Being very effective, relatively inexpensive to manufacture, and stable for a longer period. DDT was used by several countries to control malaria (Turusov et al., 2002). DDT played a major role in the malaria eradication efforts of Italy and USA (IARC, 2015). In Italy, cases of malaria decreased from 4,00,000 in 1946 to virtually none in 1950. DDT was also used to control an epidemic of typhus in Italy and Germany during 1943. In India, DDT is used mainly for "Indoor Residual Spraying (IRS)" for the control of malaria vectors. IRS has been very effective in bringing down the mortality due to malaria from 932 in the year 2000 to a meagre 96 in 2018 (NVBDCP, 2016). The number of malaria cases also drastically reduced from 2.03 million in 2000 to 0.34 million cases in 2018 (NVBDCP, 2016).

In spite of DDT's successful use to control vector borne diseases (VBDs), its widespread use has resulted in the contamination of the environment. DDT is immobile in most soils and sediments. DDT does not undergo degradation easily and residues remain for decades *i.e.*, persistent. Its half-life (*i.e.,* the time required for 50% degradation under natural environmental conditions) varies between15-20 years (Ricking and Schwarzbauer, 2012). Biotic and abiotic processes such as runoff, volatilization, photolysis and biodegradation contribute its breakdown in the environment very slowly. Its breakdown products in the soil environment are DDE and DDD, which are also highly persistent and have similar chemical and physical properties as that of the parent molecule. DDT and its degradation products are semi-volatile in nature (slowly evaporate from soil to the atmosphere due to persistence in the atmosphere). In the atmospheric air, DDT can travel long distances (long-range transboundary movement) and undergo deposition where it is never produced or used (Schenker et al., 2008).

DDT and its degradation products are sparingly soluble in water but highly soluble in fats and lipids *i.e*., lipophilic. Due to this property, DDT and its metabolites undergo enrichment in fatty tissues and accumulate in the food chain, *i.e.,* bioaccumulation. Also, progressive magnification of DDT concentration at all tropic levels of food chain occurs, leading to serious ecological and adverse human health problems (IARC 2015). The adverse effects of DDT and other organochlorine pesticides were first brought to the public by Rachel Carson through her famous book "The silent spring" in 1962. DDT causes impaired calcium metabolism among other adverse effects such as endocrine disruption, reproductive disorders,

etc (Rogan and Chen, 2005). These eco-toxicological effects led to the ban of DDT in USA in 1972 by the United States Environmental Protection Agency (USEPA) (Dunlap, 1978). Extensive use of DDT has also resulted in the development of resistance by various pests and vectors (Van den, 2009, Dash et al., 2008). India banned the use of DDT in agriculture in 1989; however, as per the recommendation of the World Health Organization (WHO), DDT is continued to be used for IRS in malaria control as it is more effective in the control of vectors. Several countries have stopped manufacturing DDT due to their obligation to Stockholm Convention. China stopped manufacturing DDT in 2014. DDT is currently manufactured only in India by HIL (India) Ltd (Formerly M/s Hindustan Insecticides Ltd), a public sector undertaking of Govt. of India. HIL (India) Ltd also exports DDT to a few African countries for public health use (HIL, Website).

### 1.2. Stockholm Convention on POPs

Stockholm Convention on Persistent Organic Pollutants (SC POPs) is an international treaty under the aegis of United Nations Environmental Program (UNEP) adopted on 18$^{th}$ February 2001 and entered into force on 17$^{th}$ May 2004. The objective of SC POPs is to protect human health and the environment from highly harmful chemicals that persist in the environment. The Convention requires countries (or parties), which signed the convention to eliminate or minimize the use of certain organic chemicals classified as POPs, which have the potential of persistence in the environment, undergo bioaccumulation in food chain and cause adverse health effects. The Stockholm convention initially listed 12 chemicals as POPs and asked countries to eliminate or minimize the production and use of POPs. DDT was one of the chlorinated pesticide included in the initial list of 12 chemicals.

The government of India (GoI) signed the Stockholm Convention (SC) on POPs on 14 May 2002 and ratified it on 13$^{th}$ January 2006. SC POPs listed DDT under Annexure B of the convention *i.e.*, restricted use, with the exemption for use in vector control, until cost-effective, locally available alternatives are not made available. All parties need to submit their action plan giving details of manufacture, use, stockpiles, and phase-out or minimization strategy to secretariat of Stockholm convention. India has submitted its action plan for the management of these 12 POPs in the form of National Implementation Plan (NIP) to the Secretariat of the Stockholm convention on 21$^{st}$ April 2011 (MoEFCC, 2011). As per the long-term action plan of India, the development and promotion of non-POPs alternatives to DDT is one of the top priorities. In India, pesticides are regulated under the Insecticides Act

1968 and Insecticides Rules 1971 of the Ministry of Agriculture and Farmer Welfare, Government of India. All the organochlorine pesticides listed as POPs have been banned for manufacture, use and import. However, as per the exemption granted by SC, and in accordance with WHO guidelines, DDT is allowed for manufacture for vector control purposes only (Table-1).

**Table- 1: Legal status of POPs pesticides in India**

| Sl. No. | Name of chemical | Category | Regulatory status in India | Date of notification |
|---|---|---|---|---|
| **1** | Aldrin | Pesticide | Banned for manufacture, use and import | 20th Sept 1996 |
| **2** | Chlordane | Pesticide | Banned manufacture, use and import | 20th Sept 1996 |
| **3** | Chlordecone | Pesticide | Banned for manufacture, use, import, export etc. | 5th March 2018 |
| **4** | DDT | Pesticide | Banned with restricted use for Vector control | 26th May 1989 |
| **5** | Dieldrin | Pesticide | Banned manufacture, use and import | 17th July 2001 |
| **6** | Endosulfan | Pesticide | Banned by the supreme court | 13th May 2011 |
| **7** | Endrin | Pesticide | Banned manufacture, use and import | 15th May 1990 |
| **8** | Heptachlor | Pesticide | Banned manufacture, use and import | 20th Sep 1996 |
| **9** | Hexachlorobenzene (HCB) | Pesticide/industrial chemical | Never registered as pesticide, but banned from manufacture, use and import | 27th March 2014 |
| **10** | Lindane | Pesticide | Banned from manufacture, import or formulate | 25th March 2011 and banned for use w.e.f. 25th March, 2013 |
| **11** | Mirex | Pesticide | Never registered | 27th March 2014 |
| **12** | Pentachlorobenzene | Pesticide/ industrial chemical | Banned for manufacture, use, import, export etc. | 5th March 2018 |
| **13** | Toxaphene | Pesticide | Banned manufacture, use and import | 25th July 1989 |

**Source:** NIP India (2011), Central insecticide board and registration committee (CIB & RC) website

During the negotiations that led to the convention, there was some concern that an immediate ban on DDT use could adversely affect the VBDs burden, particularly in tropical countries as vector control is an essential component of malaria control programs. In India, DDT is used in IRS for the control of malaria vectors. Earlier, it was also used for the control of visceral leishmaniasis (kala-azar) in India. Thus, DDT was permitted to be produced and used for vector control in accordance with recommendations and guidelines of the WHO when locally safe, effective, and affordable alternatives are not available. Progress in global malaria control over the past decade was largely attained through the rapid scale-up of vector control. According to the world malaria report (WHO, 2020), between 2000 and 2012, estimated global malaria mortality fell by 45% in all age groups and by 51% in children under 5 years. WHO has reaffirmed the importance of vector control through IRS as one of the primary interventions for reducing malaria transmission in countries having stable *i.e.,* endemic areas and unstable transmission zones *i.e.,* non- endemic or seasonal outbreak areas.

WHO recommended twelve insecticides for IRS, among which DDT and pyrethroids are the most cost-effective public health pesticides. The course of action promoted by the WHO has been to retain DDT as part of the arsenal of insecticides available for IRS globally, to be able to manage insecticide resistance until suitable alternatives are available (WHO 2015). The use of DDT for IRS is recommended only where the intervention is appropriate and effective in the local epidemiological situation (Van den et al., 2017). One of the advantages of DDT is its low cost (Walker, 2000). HIL produced 658 metric tons of technical grade DDT during 2021-22 (HIL Communication, 2022).

### 1.3. Current situation of the production and use of DDT

According to SC POPs, all countries should eliminate the production and use of DDT except for those countries that have notified the Secretariat of their intention to produce or use it for the sole use of VBD control. Such production and use are to occur in accordance with WHO recommendations and guidelines and when "locally safe, effective and affordable alternatives are not available to the countries (WHO, 2001)". Those countries that continue to use DDT until technically and economically feasible alternative products, practices and processes are not made available to them must notify the Secretariat. The list of such countries is included in the DDT register, which is publicly available. Registered parties/countries will be required to report the following details to the Secretariat of the Stockholm Convention every three years.

- the quantity used, conditions of use, and relevance to the Party's disease management strategy; and
- Measures taken to improve health care to reduce the incidence of malaria.

The convention urges parties/countries to include an action plan specific to DDT within the NIP that specifies how DDT use will be confined to disease vector management (Stockholm convention, 2017).

### 1.4. Status of DDT in India

Malaria-control demonstration projects between 1948-1952 revealed the effectiveness of DDT in interrupting transmission even at a dosage as low as 0.5g/$m^2$. In 1953, Govt of India launched the National Malaria Control Program (NMCP) which recommended IRS with DDT at 1g/$m^2$. Due to DDT's tremendous success in controlling malaria, NMCP was renamed as "National Malaria Eradication Program (NMEP)", thus India joined WHO's Global Malaria Eradication Program. Subsequently, other VBDs viz. Kala-azar, Dengue, Lymphatic Filariasis, Japanese Encephalitis and Chikungunya control were integrated under one organization and NMEP was renamed as National Vector Borne Disease Control Programme (NVBDCP) with the mandate of prevention and control of six VBDs including malaria. In 2021, NVBDCP has been renamed as National Center for Vector Borne Diseases Control (NCVBDC).

The requirement of DDT by various states for IRS is evaluated by the DDT mandate committee and accordingly, NCVBDC places order to HIL to release the quantity as per the requirement. The year-wise supply of DDT is given in Table- 2. Technical grade DDT is formulated into DDT 50 % and 75 % wettable powder (WP). In India, DDT 50% WP is supplied to states directly by HIL and Figure- 1 provides the state-wise supply of DDT for 1990-2020.

Currently, DDT is produced by HIL (India) Ltd production unit located in Rasayani, Maharashtra. The other production units of HIL (India) Ltd viz. Bathinda and Udyogmandal (Cochin), Kerala have already stopped production of DDT. DDT production details for the last 2014-15 to 2022-23 (upto Nov. 2022) are shown in Table- 3 [HIL (India) Ltd communication, 2022].

**Table- 2: Year-wise supply of DDT to NCVBDC (Source: HIL communication 2022)**

| Sl. No. | Year | Amount in MT |
|---|---|---|
| 1 | 1990-1991 | 12,844.95 |
| 2 | 1991-1992 | 11,733.50 |
| 3 | 1992-1993 | 11,525.00 |
| 4 | 1993-1994 | 12,752.40 |
| 5 | 1994-1995 | 8,533.80 |
| 6 | 1995-1996 | 10,850.00 |
| 7 | 1996-1997 | 8,206.20 |
| 8 | 1997-1998 | 8,542.00 |
| 9 | 1998-1999 | 6,800.00 |
| 10 | 1999-2000 | 7,500.00 |
| 11 | 2000-2001 | 7,000.00 |
| 12 | 2001-2002 | 6,150.00 |
| 13 | 2002-2003 | 6,042.00 |
| 14 | 2003-2004 | 8,208.00 |
| 15 | 2004-2005 | 8,500.00 |
| 16 | 2005-2006 | 8,560.00 |
| 17 | 2006-2007 | 6,825.00 |
| 18 | 2007-2008 | 6,000.00 |
| 19 | 2008-2009 | 6,821.00 |
| 20 | 2014-2015 | 6328.25 |
| 21 | 2015-2016 | 4223.00 |
| 22 | 2016-2017 | 3800.00 |
| 23 | 2017-2018 | 2981.00 |
| 24 | 2018-2019 | 2910.00 |
| 25 | 2019-2020 | 1956.00 |
| 26 | 2020-2021 | 500.00 |
| 27 | 2021-2022 | 610.00 |
| 28 | 2022-2023 | 556.00 |

**Table- 3: DDT production statement for the last five years (Source: HIL communication 2022)**

| Sl. No. | Products | Year-wise production (MT) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **2014-15** | **2015-16** | **2016-17** | **2017-18** | **2018-19** | **2019-20** | **2020-21** | **2021-22** | **2022-23(up to Nov 2022** |
| 1 | **DDT technical** | | | | | | | | | |
| | Udyog Mandal Unit (Kerala) | 588.000 | 280.000 | 254.400 | 151.400 | 0 | 0 | 0 | 0 | 0 |
| | Rasayani Unit (Maharashtra) | 3038.000 | 1814.400 | 2018.800 | 1758.400 | 1366.400 | 1200 | 568.4 | 658 | 252 |
| | **TOTAL** | **3626.000** | **2094.400** | **2273.200** | **1909.800** | **1366.400** | **1200** | **568.4** | **658** | **252** |
| 2 | **DDT formulations (DDT 50% WDP)** | | | | | | | | | |
| | Udyogmandal Unit (Kerala) | 804.000 | 541.000 | 342.000 | 200.000 | 0 | 0 | 0 | 0 | 0 |
| | Rasayani Unit (Maharashtra) | 4858.500 | 3678.000 | 3548.000 | 2781.000 | 2910.000 | 1668 | 888 | 763 | 380 |
| | **TOTAL** | **5662.000** | **4219.000** | **3800.000** | **2981.000** | **2910.000** | **1668** | **888** | **763** | **380** |
| 3 | **DDT 75% WP (exports) Rasayani Units** | **366.351** | **373.422** | **54.734** | **429.170** | **128.000** | **316.49** | **148.99** | **384.56** | **18.01** |

Technical grade DDT is made into different formulations such as wettable powder (WP 50% and 75%), emulsifiable concentrates and granules. In India, DDT WP 50% is used for IRS, whereas DDT WP 75% is used in African countries.

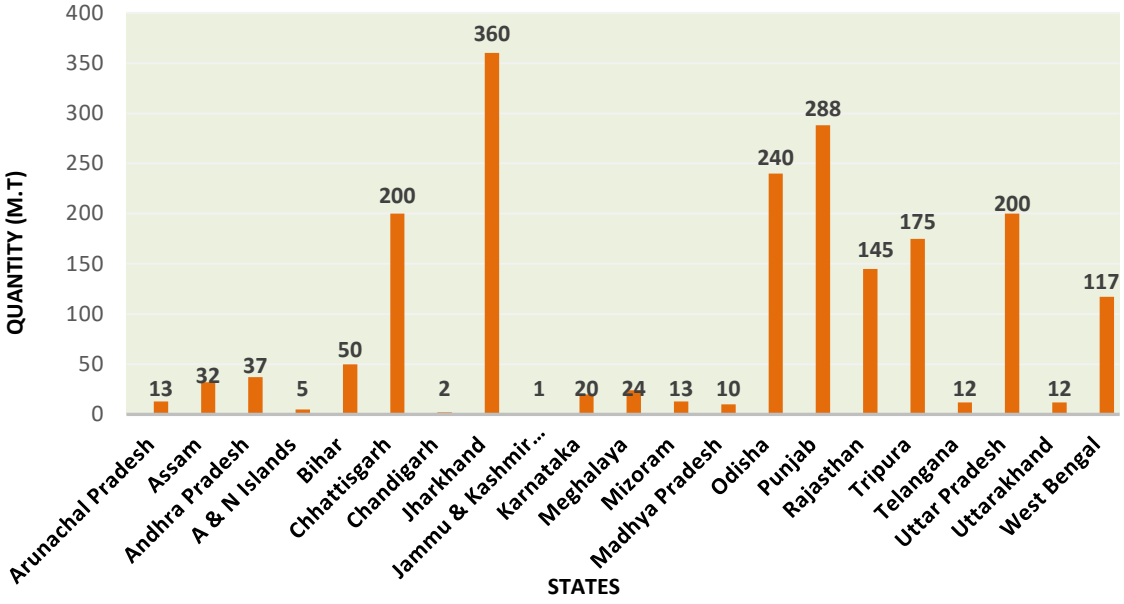



**Figure- 1: State-wise supply of DDT 50% WP during 2019-2020 for IRS**

**(Source: HIL communication 2022)**

### 1.5. Alternatives to chemical pesticides in vector control

Globally, most of the chlorinated pesticides including DDT have been phased out from use in agriculture as well as for public health purposes. This global action by countries was due to the mounting evidence of adverse health effects such as endocrine disruption, carcinogenicity, and reproductive toxicity among others (Van den H, et al., 2017). WHO (2011) emphasizes that "countries can use DDT for as long as necessary, in the quantity needed, provided that the guidelines and recommendations of WHO and the Stockholm Convention are met, and until locally appropriate and cost-effective alternatives are available for a sustainable transition from DDT". WHO also advises countries to reduce their reliance on DDT by adopting Integrated Vector Management (IVM) which promotes decision-making criteria and management procedures that ensure the best local mix of alternatives at a given place and time (WHO, 2012). Several alternate chemical and non-chemical vector control methods are available which are given in Tables- 4 and 5.

#### 1.5.1. Global Alliance for alternatives to DDT

Global Alliance for alternatives to DDT is a forum of Vector Control Experts under UNEP. Membership in this forum is open to member countries, Non-Governmental Organizations (NGOs), civil society and individuals (UNEP, 2015). The mission of the Global Alliance is to

support the development and deployment of alternative products, methods and strategies to DDT for vector control.

The Global Alliance will cover four goals 1) Strengthen the base of knowledge available to inform policy formulation and decision making, 2) Overcome the complexity and cost of deploying alternatives to DDT, 3) Make available new alternative vector control chemicals and 4) Develop non-chemical products and approaches for vector control (Figure- 2) to ensure the coordinated implementation of interventions required for each of the challenges. The Global Alliance will need to incorporate in an overall planning exercise the various time horizons and chances of success of all the interventions involved in addressing the whole range of challenges.

The Global Alliance works as a coordination and information exchange platform between its members and is active in the following ways:

- It collects and shares knowledge about available new alternatives (both chemical and non-chemical) to DDT as a vector control
- It supports in-country decisions and policy formulation in compliance with the legally binding requirements under the Stockholm Convention
- It addresses the issue of barriers to the discovery and development of new alternatives to DDT

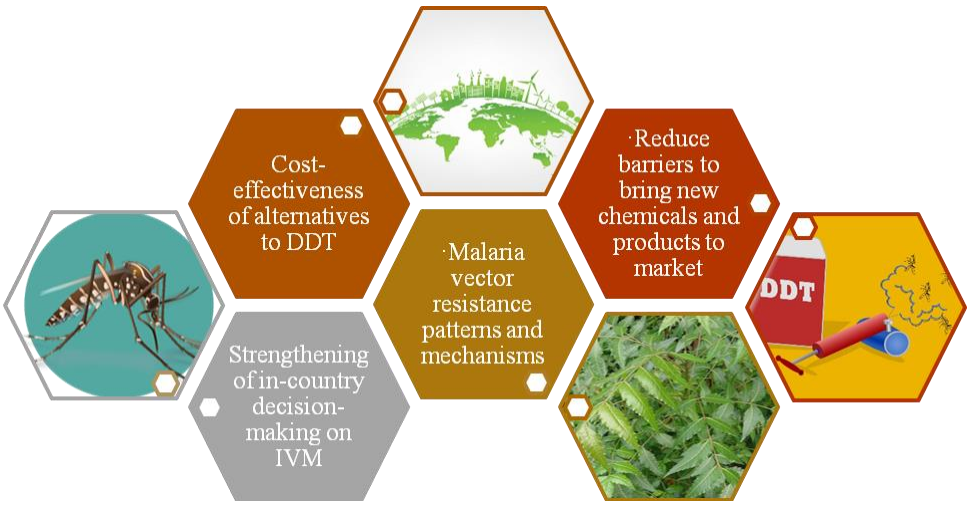



**Figure- 2: Four goals of Global Alliance**

UNEP has prepared a roadmap to various strategies to eliminate DDT in cooperation with relevant stakeholders (Figure- 3).

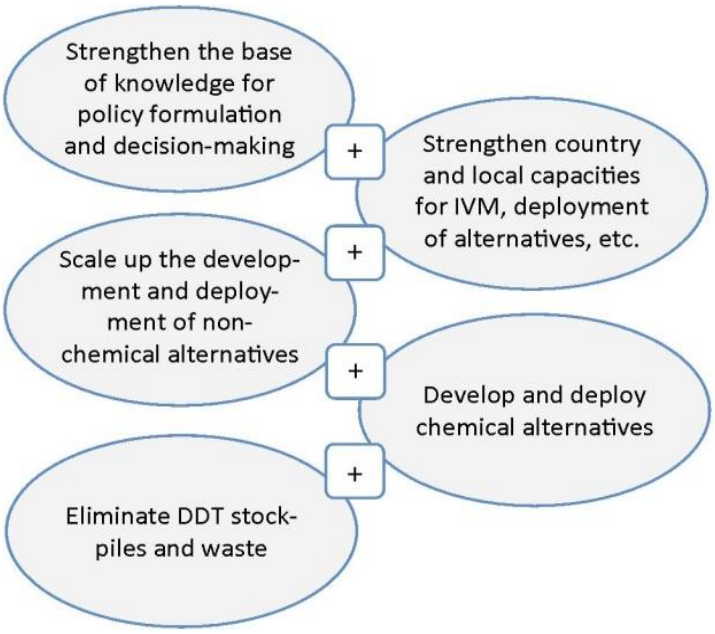



**Figure- 3: Road map for the development of alternatives to DDT (Ref. SC POPs Website)**

**The Global Alliance strategy**

The strategy of the Global Alliance is to trigger significant action to develop and deploy alternatives to DDT by focusing on:

- Mobilizing stakeholders around a common agenda to develop and deploy alternatives to DDT for disease vector control;
- Facilitating stakeholder interactions in order to strengthen and complement existing initiatives and reduce duplication;
- Identifying and supporting specific opportunities where involvement of actors from diverse cross-sector stakeholder groups is necessary or where a "vacuum" of activities is identified;
- Encouraging investments to develop and deploy alternatives to DDT for disease vector control

In Table- 4, the various strategies for vector control and in Table-5 various methods available are shown that can reduce the reliance on chemical pesticides in vector control. Apart from the conventional tools of vector control, efforts should be made to identify and promote possible non-chemical vector control tools used within communities inherited from traditional practices (Details provided in Module no. 4).

**Table- 4: Different alternatives to DDT in vector control**

| Sl. No. | Factors | Methods | Types of control |
|---|---|---|---|
| 1 | **Larval control** | **Environmental management (ecosystem compatible removal of mosquito breeding sites):** Environmental modification (draining wetlands, constructing drainage canals, covering water tanks and stagnant water, land leveling, filling depressions and pools of water), environmental manipulation (irrigation management, clearing of vegetation, planting of trees, removal of trash). | Prevention |
| | | **Ecosystem compatible predators** (larvivorous fishes, crustaceans [copepods]) and nematodes (under development). | |
| | | **Bacterial larvicides** (*Bacillus thuringiensis var. isaraelensis* and **Botanical larvicides** (*Azadirachta indica*). | |
| 2 | **Reducing man/vector contact** | **Chemical larvicide**<br>**House improvement**<br>**Improved sanitation, use of full clothes, botanical repellents** (neem, *citronella*), **mosquito nets and screens** | Prevention & control |
| | | **Insecticide Treated Nets & chemical repellents** | |
| 3 | **Mosquito control** | **Mosquito traps and targets** | Vector control |
| | | **Botanical pesticides** (pyrethrum )<br>**Fungi** (under development) | |
| | | **Sterile Insect Technique** | |
| | | **Sponging cattle with insecticides** | |
| | | **Indoor-Residual Spray with insecticides** | |
| | | **Space spraying of insecticides** | |

**Source: PAN Germany 2013**

**Table- 5: Alternative methods and practices that could phase out DDT in vector control**

| Sl. No. | Vector management practices | Control process |
|---|---|---|
| **1** | **Source reduction** | Eliminating vector breeding habitat through drainage, land levelling, filling and controlling larval development, reduce Manmade habitats are generally the easiest target. |
| **2** | **Manipulation of natural habitat** | Cleaning water bodies, flushing of streams, straightening of riverbanks, and impounded water to prevent vector breeding. Provided sunny or shaded conditions. |
| **3** | **Irrigation management** | Good irrigation structure so that water does not stagnate for long. See that flooding is not done where not required. |
| **4** | **House improvement** | Proper construction and screening could reduce mosquitoes by 3 times. Plastering of walls and ceiling fills the crevices that serve as a refuge for adult mosquitoes. |
| **5** | **Predators** | Larvivorous fish *Gambusia affinis* and *Poecilia reticulata* (Guppy) have frequently been reared and released for controlling vector breeding in small water tanks and wells. Mosquito larvae easy prey for aquatic predators' crustacean and larvivorous fish. |
| **6** | **Polystyrene beads** | Expanded polystyrene beads have been used to control vector breeding in small confined water collections, for example in borrow pits, wells or small water tanks. A thin layer prevents egg deposition and causes the suffocation of mosquito larvae present in the water. |
| **7** | **Genetic methods** | Two genetic approaches – 1) the sterile insect technique involves the introduction of specific genes into a wild vector population through mating; 2) the genetic modification of the ability of the natural vector population to transmit the parasite. |
| **8** | **Microbial larvicides** | *Bacillus thuringiensis var. israelensis* and produce toxins that are used in formulations as microbial larvicides. They are toxic to mosquitoes only. Conventional microbial strains, and recombinant bacteria are being developed. |

| | | |
|---|---|---|
| **9** | **Plant products** | The traditional burning of local plants and leaves is commonly used for its mosquito-repellent effect; such as the burning of dried neem leaves and cake, neem-based IRS. There are herbs such as basil that can repel mosquitoes. Some of the plant extracts e.g., Rotenone, Pyrethrum, *Nigella sativa*, and *Jatropha curcas* are also used. |
| **10** | **Fungi** | Selected fungi have shown promising results for controlling adult *Anopheles* mosquitoes e.g., *Beauvaria bassiana, Metarhizium anisopliae* etc. |
| **11** | **Zooprophylaxis** | It refers to attracting vectors to domestic animals in the pathogen cannot amplify. In areas where malaria vectors have a strong preference to feed on livestock rather than on humans, the spatial planning of livestock management can, in theory, reduce malaria transmission in humans. |
| **12** | **Chemical methods** | Some of the chemicals approved by NCVBDC, which are not having persistent properties like Malathion 25% WDP – IRS, Synthetic Pyrethroids -IRS, Deltamethrin, Cyfluthrin, Bifenthrin, Lambdacyhalothrin, Alphacypermethrin, Malathion Technical- Fogging, Temephos 50% EC can also be used as an alternative of DDT |

**Source: Van den, 2009 and UNEP, 2009**

## 2. Introduction to Vector Borne Diseases

**Learning Objectives**

At the end of the training programme, participants should be able to

- Describe the vectors, pathogens and their role in Vector Borne Disease
- Describe the basic information about vector borne diseases
- Describe how vector borne diseases are transmitted
- Describe the transmission cycle for respective vector borne diseases
- Describe the global distribution as well as burden of the diseases in India

### Vector

A vector is a living organism that transmits a pathogen (viruses, bacteria, fungi and parasites) from one infected person (or animal) to another, causing serious disease in the human population. Vectors are generally arthropods, such as mosquitoes, flies, fleas, ticks, mites and lice. Many of these vectors are bloodsucking insects, which ingest disease-producing microorganisms during a blood meal from an infected host (human or animal) and later transmit it into a new host after the pathogen has replicated or morphologically transformed.

Pathogens are infectious agents, which can be defined as organisms causing diseases or infections to their host. A pathogen may be transmitted from its natural reservoir to a susceptible host in different ways. There are direct and indirect modes of transmission. In direct transmission, an infectious agent is transferred from a reservoir to a susceptible host by direct contact or droplet spread, while indirect transmission indicates the transfer of an infectious agent from a reservoir to a host by suspended air particles, inanimate objects (vehicles), or animate intermediaries (vectors). The transmission of pathogens by a vector may be mechanical or biological. In the former case, the pathogen is mechanically transported by the flying arthropod through soiling of its feet or proboscis and there is no development or multiplication of the pathogen on or within the vector while in the latter case, the pathogen passes through a propagative, cyclic or cyclo-propagative development in the vector (Park, 2015). Transovarial transmission is a mechanism by which infective mosquitoes pass the virus to their offspring via their eggs. Transstadial transmission is the sequential passage of a pathogen from one developmental stage (stadium) of the host to its subsequent stage or stages, particularly as seen in mites.

**Vector Borne Diseases (VBDs)**

The Vector Borne Diseases (VBDs) pose a major threat in tropical and subtropical countries including India, affect not only the individuals but the community resulting in social distress and economic burden. The Vector Borne Diseases are infections caused by pathogens, which are transmitted by hematophagous arthropod vectors (bedbugs, biting midges, black flies, fleas, kissing bugs, lice, mosquitoes, sand flies, ticks and mites). People suffer from a significant disease burden from these diseases in local and focal areas of India, which is reflected in the form of morbidity and mortality from Malaria, Dengue, Chikungunya, Japanese Encephalitis (JE), Kala-azar, Lymphatic Filariasis, etc. Our country has made impressive gains towards the elimination of Malaria, LF and Kala-azar. However, the burden of many other arboviral diseases like Dengue, Chikungunya and Japanese Encephalitis has increased in recent years with repeated outbreaks in many parts of the country. Re-emerging diseases like Zika virus infection, Chandipura fever, CCHF fever, KFD and Scrub Typhus are also adding to a public health concern. These diseases are caused by pathogenic agents such as viruses, bacteria, protozoa and helminths etc. Among the hematophagous arthropod vectors, mosquitoes are the leading vectors for human infectious agents, meanwhile, ticks are the leading vectors for the vast majority of zoonosis worldwide. Some of the major VBDs are mentioned in the following section.

# 2.1 MALARIA

## 2.1.1 Introduction

Malaria is a mosquito borne communicable disease, which is transmitted to humans by female mosquitoes of the genus *Anopheles*. Malaria continues to be a major public health problem in India. The majority of deaths due to VBDs are associated with malaria. The common signs and symptoms of malaria are cyclic high fever, headache, rigours, chills, profuse sweating, nausea, vomiting, diarrhoea, anaemia, muscle pain, convulsions etc. If not treated promptly, the infection may become serious and responsible for kidney failure, seizures, mental confusion, coma and death. The initial symptoms, which may be mild, may not be easy to diagnose. Other symptoms related to organ failure may supervene, such as acute renal failure, pulmonary edema and circulatory collapse. Symptoms usually begin 10-15 days after getting infected by a vector mosquito bite. Young children and pregnant women are immuno-suppressed and elderly travellers are particularly at risk of severe disease. Human malaria caused by other *Plasmodium vivax* species results in significant morbidity but is rarely life-threatening. Malaria, particularly *P. falciparum*, in pregnant women, increases the risk of maternal death, miscarriage, stillbirth and neonatal death.

Malaria is a public health problem in several parts of the country. About 95% population in the country resides in malaria-endemic areas and 80% of malaria reported in the country is confined to areas consisting 20% of the population residing in tribal, hilly, difficult and inaccessible areas. As per the NCVBDC, India has reported 161516 confirmed malaria cases and 90 associated deaths in 2021. (https://nvbdcp.gov.in). In 2020, 29 of the 85 malaria-endemic countries accounted for 96% of malaria cases. India contributed to 1.7% of malaria cases and 1.2% of deaths globally (World Malaria Report, 2021).

## 2.1.2 Causative agent and vector

The causative agents of malaria are unicellular protozoan parasites belonging to the genus *Plasmodium* of Phylum Protozoa. *Plasmodium* species that cause malaria in large areas of the world are five species viz. *P. falciparum*, *P. vivax*, *P. malariae*, *P. ovale* and *P. knowlesi*. The first four are specific for humans, while *P. knowlesi* is naturally maintained in macaque monkeys, causes zoonotic malaria widely in South East Asia (Sato, 2021) and so far reported only from Andaman and Nicobar Islands (Subbarao et al., 2019).

Human malaria is transmitted only by the infective bite of females of the genus *Anopheles* vector mosquito. There are approximately 3,500 species of mosquitoes grouped into 41 genera, but of the nearly 465 *Anopheles* species are recognized. Approximately 70 of these species can transmit human malaria parasites in nature and 41 are considered here to be dominant vector species. The rest, even biting humans frequently, cannot sustain development of malaria parasites. In India, the anophelines fauna comprises 58 species, out of which only six are primary malaria vectors and three secondary vectors (Nagpal and Sharma, 1995). Primary vectors are- *An. culicifacies, An. stephensi*, *An. fluviatilis*, *An. minimus, An. baimaii* [formerly known as *An. dirus* species D (Sallum et al., 2005)] and *An. sundaicus* species A, also known as *An. epiroticus* Linton & Harbach (Linton et al., 2005), and secondary vectors are- *An. varuna, An. annularis* and *An. philippinesis*. All these vectors play important role in malaria transmission in India.

### 2.1.3 Transmission and life cycle

Only mosquitoes belonging to the genus *Anopheles* transmit the parasites causing human malaria. All of the vector species bite between dusk and dawn. The intensity of transmission depends on factors related to the parasite, vector, human host, and environment. The female mosquitoes seek a blood meal to develop their eggs.

Transmission is more intense in places where the mosquito's lifespan is longer and where it prefers to bite humans rather than other animals. The transmission also depends on climatic conditions that may affect the number and survival of mosquitoes, such as rainfall patterns, temperature and humidity. In many places, transmission is seasonal, with the peak during and post-monsoon season. Malaria epidemics can occur when climate and other conditions suddenly favour transmission in areas where people have little or no immunity to malaria. They can also occur when people with low immunity move into areas (for tourism, to find work, as refugees, etc.) with intense malaria transmission.

The malaria parasite undergoes two cycles of development viz. the human cycle (asexual cycle) and the mosquito cycle (sexual cycle). The malaria parasite life cycle involves two hosts viz. man as the intermediate host and mosquito as the definitive host (Figure- 4).

**Asexual cycle in humans:** The asexual cycle begins when an infected female *Anopheles* mosquito bites a person and injects sporozoites.

**Pre-erythrocytic (Hepatic) or Exo-erythrocytic cycle**

After the inoculation of sporozoites into the human body by a malaria-infected female *Anopheles* mosquito, the sporozoites disappear within 60 minutes from the peripheral circulation. Many of them are destroyed by phagocytes, but some reach liver cells. After 1-2 weeks of development (depending upon the species), they become hepatic schizonts, which eventually burst to release a shower of merozoites (in *P. vivax* and *P. ovale*- a dormant stage *i.e.*, hypnozoites can persist in the liver, if untreated and cause relapses by invading the bloodstream weeks or even years later). In *P. falciparum*, the intrahepatic schizonts rupture almost simultaneously and there is no persistent tissue phase (exo-erythrocytic cycle).

**Erythrocytic cycle**

Many of the merozoites released from the liver cells are quickly destroyed, but a significant number attach themselves to specific receptor sites on the Red Blood Corpuscles (RBCs), then penetrate the RBC and pass-through various stages of trophozoite and schizonts. The erythrocytic cycle ends with the liberation of merozoites, which infect fresh RBCs.

The clinical feature of fever with chills coincides generally with the rupture of RBCs. The cycle is repeated over and over again until the condition worsens or when it may be slowed down by the immune response of the host. The duration of each erythrocytic cycle varies between species- 48 hours for *P. falciparum*, *P.* v*ivax* and *P. ovale* and 72 hours for *P. malariae*. Blood-stage parasites are responsible for the clinical manifestations of the disease.

**Gametogony phase**

Some of the erythrocytic forms of plasmodia leave the cycle of asexual multiplication and do not divide further but develop into sexual forms viz. male (microgametocytes) and female (macrogametocytes) gametocytes. These gametocytes circulate in the bloodstream and do not cause any symptoms in humans but they are sexual forms of the parasite, which are infective to mosquitoes. Currently, those harbouring such sexual forms of gametocytes circulating in the blood are also referred to as asymptomatic carriers.

**Sexual cycle in mosquito body**: The sexual cycle begins when the female *Anopheles* mosquito ingests these gametocytes during a blood meal.

**Sporogony Cycle**

In the mosquito's stomach, the gametocytes, develop further into mature sex cells. The first process of exflagellation of the male gametocyte take place in which 4-8 thread-like filaments

called microgametes are developed. The female gametocyte undergoes a process of maturation and becomes a female gamete or macrogamete. Microgametes are attracted to the female gamete and one of the microgamete cause fertilisation of the female gamete generating zygote. The zygotes transform to ookinetes, which are motile and elongated. Ookinete invades the mid-gut wall of the mosquito and develops into oocysts on the outer surface of the gut wall. Inside the oocyst, thousands of active sporozoites develop. The oocyst ultimately bursts, releasing sporozoites into the body cavity that travel to the mosquito's salivary glands. The parasites' multiplication in the mosquito is known as the sporogony cycle. Inoculation of the sporozoites into a new human host perpetuates the malaria life cycle. The duration required for the development of the parasite from the gametocyte to the sporozoite stage in the body of the mosquito is referred as the extrinsic incubation period.

The incubation interval period indicates a total period of both the cycle (asexual and sexual) and early presence of the ring stage (Early Trophozoites) indicates fresh infection. IVM and effective antimalarial drugs are very important and essentially required for the prevention and control of malaria.

When the female *Anopheles* mosquito takes a blood meal from a healthy human, anticoagulant saliva is injected together with the sporozoites, which migrate to the liver and a new cycle begins. Thus, the infected female mosquito carries the disease from one human to another (acting as a "vector"), while infected humans transmit the parasite to the mosquito.

**Other modes of transmission**

Malaria may be spread by the inoculation of blood from an infected person to a healthy person, which is rare. In this type, asexual forms are directly inoculated into the blood and pre-erythrocytic development of the parasite in the liver does not occur. Therefore, this type of malaria has a shorter incubation period and relapses due to persisting exo-erythrocytic forms do not occur. It can transmit (a) from the mother to the growing foetus known as congenital malaria and (b) transfusion of blood from infected donors known as transfusion malaria.

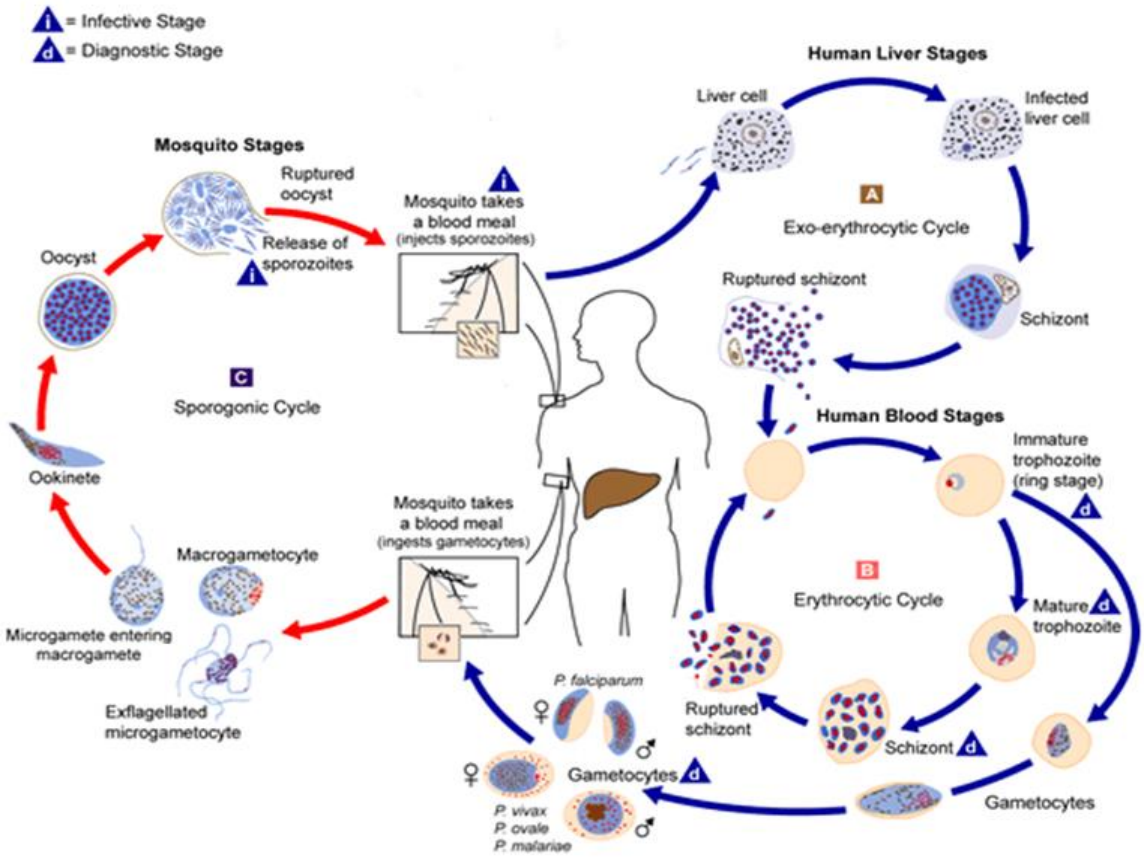



**Figure- 4: Malaria transmission cycle (CDC)**

### 2.1.4 Epidemiology

In India, the epidemiology of malaria is complex because of geo-ecological diversity, multi-ethnicity, wide distribution of nine anopheline vectors transmitting three plasmodial malaria pathogens, drug resistance in parasites and insecticide resistance in vectors. The high endemic areas contribute up to 80% of malaria cases in the country. Around 95% of the country's population lives in malaria-endemic areas, 80% of malaria occurs in 20% of areas classified as 'high-risk population'. The high malaria endemic states include Andhra Pradesh, Chhattisgarh, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, and seven north-eastern states. The state of Odisha, although constituting only 4% of India's population, contributes 22% of total malaria cases and 43% of total *P. falciparum* cases along with around 50% of deaths attributed to malaria in the country. In India, nine Anopheline vectors are involved in transmitting malaria in diverse geo-ecological paradigms. About 2 million confirmed malaria cases and 1,000 deaths are reported annually, although 15 million cases and 20,000 deaths are estimated by WHO South East Asia Regional Office (Kumar et al., 2007)

At the time of India's independence in 1947, nearly 75 million malaria cases were estimated in a population of 330 million. With the effective implementation of NMEP, malaria significantly declined to 49151 cases and no deaths in 1961. However, a resurgence was reported in the country with 6.4 million cases in 1976. As a result, the Government's Modified Plan of Operation (MPO) was implemented in the country in 1977 to eliminate malaria deaths in the country and reduction in morbidity. In the 1980s, new malaria ecotypes developed from environmental and developmental schemes were implemented. As a result of which epidemics in different parts of the country occurred during the 1990s. Malaria has remained deeply inherent in Madhya Pradesh, Chhattisgarh, Jharkhand, Odisha and the entire north-eastern region, where vast lands are inhabited by ethnic tribes. The risk of malaria varies widely, but in the case of highlands (>1,500 m) and arid areas (<1,000 mm rainfall/year), the risk is typically less, although these areas are prone to epidemic malaria, if climatic conditions become favourable to mosquito development (WHO, 1996a). Although urban areas have typically been at lower risk, explosive unplanned population growth has been a major factor in making urban or peri-urban transmission an increasing problem. The distribution of these parasites varies geographically and not all *Plasmodium* species are transmitted in all malaria areas. A rise in *P. falciparum* has also been reported and has slowly risen to nearly 50% in recent years.

### 2.1.5 Burden in India

India has 186532 reported cases of malaria with 93 deaths in 2020 (Figures- 5 & 6) maximum cases were reported from Odisha (41739), Chhattisgarh (36667) and Uttar Pradesh (28668). In 2021, the total number of cases were 161753 with 90 deaths, a maximum number of cases were from Chhattisgarh (29733), West Bengal (28987) followed by Odisha (25503). Indicators have been developed at the national level for monitoring the program and there is uniformity in the collection, compilation and submission of data (http://nvbdcp.gov.in).

In February 2016, the Government of India formally launched the National Framework for Malaria Elimination (NFME), which outlines the strategies for malaria elimination from India by 2030. NFME was disseminated to all states and UTs with instructions to initiate key actions to achieve the target in time bound manner. The malaria situation in the country from 2000 -2021 is given in the Table- 6.

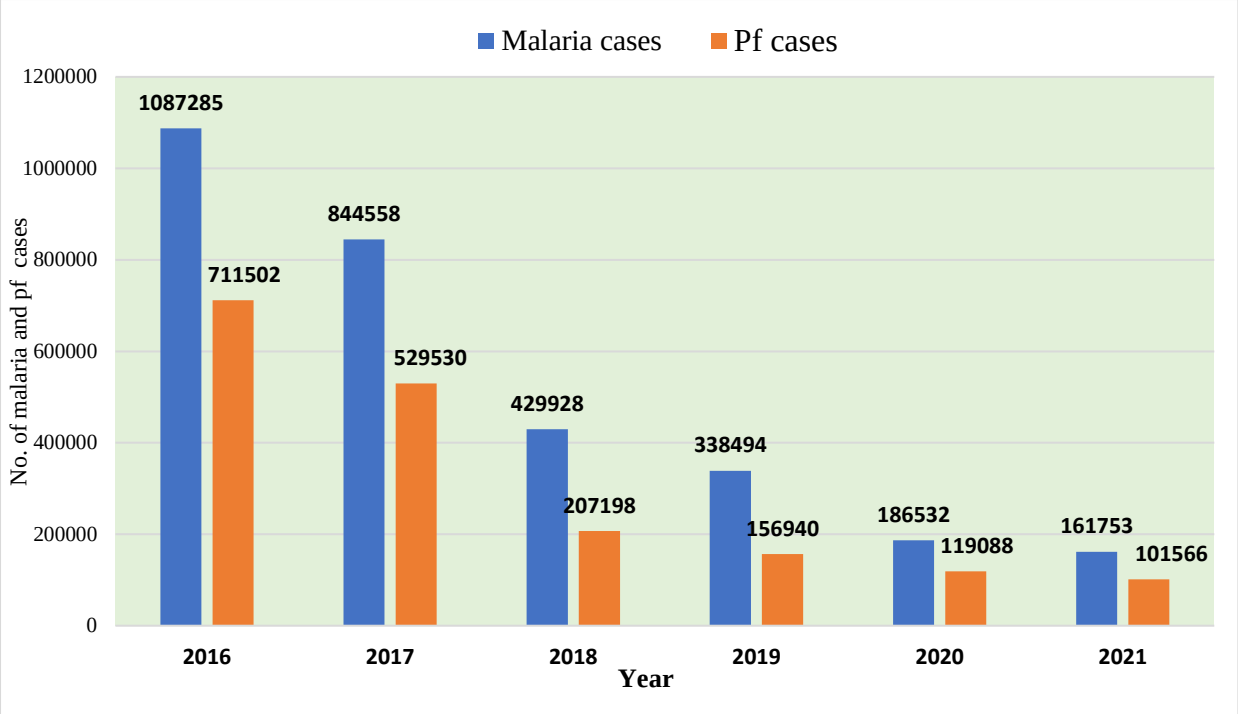



**Figure- 5: Malaria cases and *Pf* cases in India during 2016-2021**

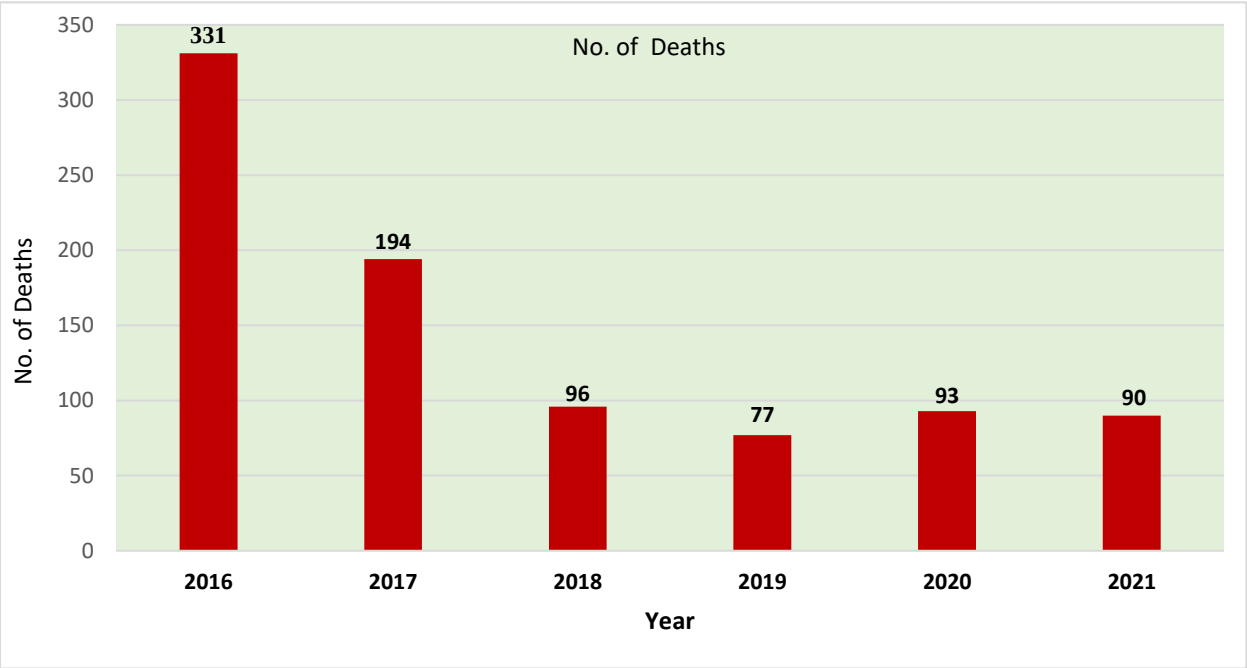



**Figure- 6: Malaria deaths in India during 2016-2021**

**Table- 6: Country-wide epidemiological situation**

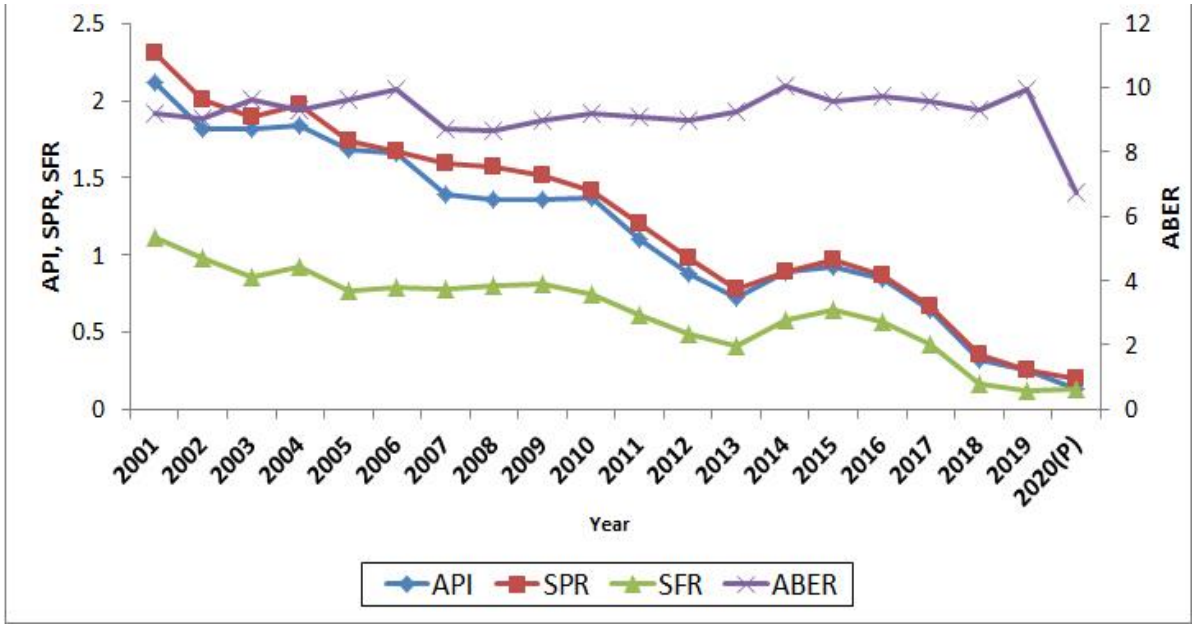
| Year | Population (thousands) | Total malaria cases (million) | *P. falciparum* cases (million) | *Pf* % | API | Deaths due to malaria |
|---|---|---|---|---|---|---|
| **2000** | 970275 | 2.03 | 1.05 | 51.54 | 2.09 | 932 |
| **2001** | 984579 | 2.09 | 1.01 | 48.20 | 2.12 | 1005 |
| **2002** | 1013942 | 1.84 | 0.90 | 48.74 | 1.82 | 973 |
| **2003** | 1027157 | 1.87 | 0.86 | 45.85 | 1.82 | 1006 |
| **2004** | 1040939 | 1.92 | 0.89 | 46.47 | 1.84 | 949 |
| **2005** | 1082882 | 1.82 | 0.81 | 44.32 | 1.68 | 963 |
| **2006** | 1072713 | 1.79 | 0.84 | 47.08 | 1.66 | 1707 |
| **2007** | 1087582 | 1.51 | 0.74 | 49.11 | 1.39 | 1311 |
| **2008** | 1119624 | 1.53 | 0.77 | 50.81 | 1.36 | 1055 |
| **2009** | 1150113 | 1.56 | 0.84 | 53.72 | 1.36 | 1144 |
| **2010** | 1167360 | 1.60 | 0.83 | 52.12 | 1.37 | 1018 |
| **2011** | 1194901 | 1.31 | 0.67 | 50.74 | 1.10 | 754 |
| **2012** | 1211580 | 1.06 | 0.53 | 49.98 | 0.88 | 519 |
| **2013** | 1221640 | 0.88 | 0.46 | 52.61 | 0.72 | 440 |
| **2014** | 1234995 | 1.10 | 0.72 | 65.55 | 0.89 | 562 |
| **2015** | 1265173 | 1.17 | 0.78 | 66.61 | 0.92 | 384 |
| **2016** | 1283303 | 1.09 | 0.71 | 65.53 | 0.85 | 331 |
| **2017** | 1315092 | 0.84 | 0.53 | 62.70 | 0.64 | 194 |
| **2018** | 1315092 | 0.42 | 0.16 | 47.93 | 0.32 | 96 |
| **2019** | 1349004 | 0.34 | 0.16 | 46.36 | 0.25 | 77 |
| **2020** | 1372316 | 0.19 | 0.12 | 63.84 | 0.14 | 93 |
| **2021** | 1385479 | 0.16 | 0.10 | 63.10 | 0.12 | 90 |

**Source: NCVBDC (**http://nvbdcp.gov.in**)**

The caseload, though steady at around 2 million cases annually in the late 1990s, has shown a declining trend since 2002. When interpreting Annual Parasite Incidence (API), it is important to evaluate the level of surveillance activity indicated by the Annual Blood

Examination Rate (ABER). At low levels of surveillance, the Slide Positivity Rate (SPR) may be considered as one of the indicators. The SPR has also shown a gradual decline from 3.50 in 1995 to 0.19 in 2020 (Table- 6). The reported P*f* cases declined from 1.14 million in 1995 to 0.10 million cases in 2021. The P*f* % gradually increased from 39 % in 1995 to 51.54 % in 2000, then fluctuated between 44.32 % and 63.84 % between 2001 and 2021 (http://nvbdcp.gov.in).

The numbers of reported deaths are around 1000 per year till 2005. The mortality peak in 2006 was related to severe malaria epidemics affecting Assam caused by population movements. Table- 6 shows that API have consistently came down from 2.12 (2001) to 0.12 (2021) and also decline trends in malaria deaths from 1707 (2006) to 90 (2021). Slide Positivity Rate (SPR) and Slide *falciparum* Rate (S*f*R) have reduced over the years (2001 to 2020).




API= Annual Parasite Incidence; SPR= Slide Positivity Rate; S*f*R= Slide *falciparum* Rate; ABER= Annual Blood slide Examination Rate.

**Figure- 7: Malaria parameters in India (NCVBDC)**

The proportion of *P. vivax* and *P. falciparum* varies in different parts of India. Although most of the Indo-Gangetic plains and northern hilly states, north-western India and Tamil Nadu have <10% *Pf* and the rest are *Pv* infections; in the forested areas inhabited by ethnic tribes, the situation is reversed and *Pf* proportion is 30–90% and in the remaining areas it is between 10 and 30% (Singh et al., 2013). In states inhabited by ethnic tribes mainly in the forest ecosystems, meso- to hyper-endemic conditions of malaria exist with the preponderance of *P.*

*falciparum* to the extent of 90% or even more. Figure- 7 revealed the malaria parameters in India from 2001 to 2020, expressed a good average of ABER, but reduced in 2020-21. The API (2.12) of 2001 has shown a significant continuously declined up to 2021 (0. 12).

### 2.1.6 Global burden

Malaria is a worldwide problem; it occurs primarily in tropical and some subtropical regions of Africa, Central and South America, Asia, and Oceania. In areas where malaria occurs, there is tremendous variation in the intensity of transmission and risk of infection. For example, over 90 per cent of clinical malaria infections and deaths occur in Sub-Saharan Africa (WHO, 1996a). Malaria has remained the greatest health and socio-economic burden in the tropical and subtropical regions of the world.

The WHO South-East Asia Region accounted for about 2% of the burden of malaria cases globally. Malaria cases reduced by 78%, from 23 million in 2000 to about 5 million in 2020. Malaria case incidence in this region reduced by 83%, from about 18 cases per 1000 population at risk in 2000 to about three cases in 2020. India accounted for 83% of cases in the region. Sri Lanka was certified malaria-free in 2016 and remains malaria free.

About 96% of malaria deaths globally were in 29 countries. Six countries – Nigeria (27%), the Democratic Republic of the Congo (12%), Uganda (5%), Mozambique (4%), Angola (3%) and Burkina Faso (3%) – accounted for just over half of all malaria deaths globally in 2020. In the WHO South-East Asia Region, malaria deaths were reduced by 75%, from about 35 000 in 2000 to 9000 in 2020. India accounted for about 82% of all malaria deaths in the WHO South-East Asia Region (World malaria report, 2021).

Malaria is preventable and curable, though in some regions malaria parasites are developing resistance to drugs and vectors are getting resistant to insecticides. Prevalence of malaria is found in the low economic regions of the world, where inhabitants of malaria-prone rural areas often have few barriers against mosquitoes in their dwellings.

## 2.2 LYMPHATIC FILARIASIS

### 2.2.1 Introduction

Lymphatic Filariasis (LF) is commonly known as 'elephantiasis' and is a neglected tropical disease. It is caused by infection with parasites classified as nematodes (roundworms) of the family Filarididae. Adult worms nest in the lymphatic vessels and disrupt the normal function of the lymphatic system. Infection is usually acquired in childhood causing hidden damage to the lymphatic system. The painful and profoundly disfiguring visible manifestations of the disease, lymphoedema, elephantiasis and scrotal swelling occur later in life and can lead to permanent disability. These patients are not only physically disabled but suffer mental, social and financial losses contributing to stigma and poverty. The disease is prevalent in 73 tropical and sub-tropical countries in South-east Asia, Africa, the Mediterranean, South Pacific and South America regions (NVBDCP 2018). In 2020, 863 million people in 47 countries were living in areas that require preventive chemotherapy to stop the spread of infection (WHO/lymphatic-filariasis 2022). In India, *Wuchereria bancrofti* transmitted by the vector *Culex quinquefasciatus* has been the most predominant infection responsible for over 99% of the problem in the country.

The global baseline estimates of people affected by LF was 25 million men with hydrocele and over 15 million people with lymphoedema. At least 36 million people remain with these chronic disease manifestations. Eliminating LF can prevent unnecessary suffering and contribute to the reduction of poverty.

### 2.2.2 Causative agent and vector

Three thread-like nematode species cause Lymphatic Filariasis in humans viz. *Wuchereria bancrofti, Brugia malayi* and *Brugia timori*. Of these, only *Wuchereria bancrofti* and *Brugia malayi* are found in India, whereas *Brugia timori* has only been found in the Lesser Sunda Islands of Indonesia. In mainland India, *W. bancrofti* transmitted by the ubiquitous vector, *Culex quinquefasciatus*, has been the most predominant infection contributing to 99.4% of the problem in the country. The infection is prevalent in urban as well as rural areas. The vector species preferably breed in dirty and polluted water (http://nvbdcp.gov.in).

*Brugia malayi* infection is mainly restricted to rural areas due to the peculiar breeding habits of the vector associated with floating aquatic vegetation. *Mansonia annulifera* is the principal

vector while *Ma. uniformis* is the secondary vector. The vectorial role of *Ma. indiana* is very limited due to its low density. These vector mosquito breed in ponds and lakes containing certain aquatic plants, especially the floating type like *Pistia stratiotes* and water hyacinth.

Both *W. bancrofti* and *B. malayi* infections in mainland India exhibit nocturnal periodicity of microfilariae. Diurnal sub-periodic *W. bancrofti* infection was reported in 1974-75 among aborigines, inhabiting Nicobar group of Andaman & Nicobar Islands and *Ochlerotatus (Finlaya) niveus* group of mosquitoes were incriminated as the vectors for this infection, formerly known as *Aedes (Finlaya) niveus*. *Ochlerotatus (Finlaya) niveus* was reclassified and is currently known as *Downsiomyia nivea* (Reinert et al., 2004; Shriram at al., 2015). Infection of LF occurs when filarial parasites are transmitted to humans through the bites of infected mosquitoes.

### 2.2.3 Transmission and life cycle

Adult worms, male and female, live in the lymphatic vessels and lymph nodes by making a nest in the dilated lymphatics, subsequently disrupting the normal function of the lymphatic system. The worms can live for approximately 6-8 years and sometimes may survive for 15 years or more. After mating, the female worm releases millions of sheathed worms in its lifetime, called microfilariae that circulate in the blood. The sheathed microfilariae begin to appear in the blood circulation in six months to one year after infection (prepatent period). People with such microfilariae in their blood are infected and can give the infection to others through mosquitoes. The microfilariae (mf) remain in the arterioles of the lungs during the day and appear in the peripheral circulation at night (nocturnally periodic). The periodicity of mf coincides with the biting activity of the vector. The sexual cycle of the parasite takes place in the human host (definitive host), where the adult worms ultimately die. The life cycle of the parasite is cyclo-developmental in the vector where the parasites do not multiply. Microfilariae don't develop at the next larval stage in the human body but they can develop into mosquito bodies whenever they get entry.

The microfilariae from an infected person are picked up by vector mosquito during the blood meal and undergo development (intermediate hosts) as L1 (inactive sausage stage), L2 (pre-infective larva) and subsequently infective larvae (L3 stage) within 7-21 days. The L3 stage larva is an infective stage of LF, which is transmitted to the human through vector mosquito's mouth parts (Proboscis) (Figure- 9). An infected mosquito punctures the host skin while

feeding and deposits L3 stage filarial larvae onto the skin of the human host, where they penetrate the bite wound/site. The larvae then migrate to the lymphatic vessels where they develop into adult worms.

**Table- 7: Periodicity and distribution of parasites that cause human lymphatic filariasis (WHO, 2013)**

| Organism | Periodicity | Distribution | Main vectors |
|---|---|---|---|
| ***Wuchereria bancrofti*** | Nocturnal periodic | Worldwide including Africa, Indonesia, Melanesia Island | *Anopheles, Culex* |
| | Nocturnal sub-periodic | Micronesia island, Middle East, South America, South Asia | *Aedes* |
| | Diurnal sub-periodic | South-East Asia, Polynesia Island | *Aedes* |
| ***Brugia malayi*** | Nocturnal periodic | India, Indonesia, South-East Asia | *Anopheles, Mansonia* |
| | Nocturnal sub-periodic<br>Diurnal sub-periodic | Indonesia, South-East Asia, Thailand | *Mansonia*<br>*Mansonia* |
| ***Brugia timori*** | Nocturnal periodic | Indonesia, Timor, Alor Island, Flores Island, Rote Island | *Anopheles* |

The mosquito carries the microfilaria from the infected host during the blood meal, thus continuing a cycle of transmission. Biotic and abiotic factors play an important role in the transmission of infection.

**In mosquito**

When the mosquito feeds on an infected person, the sheathed microfilariae are taken with the blood meal. The microfilariae shed the sheath in the gut and penetrate the gut wall of the mosquito. Later they enter the thoracic muscles, where they develop into thick, short forms with a tail. This stage is called the "sausage form" with an average size of 200 microns. The complete development of 1$^{st}$ stage larva (L1) takes place in two or three days. The tail portion

is lost during further growth. The 2nd stage larval (L2) development completes in 5-7 days. The average size of the 2nd stage larva (L2) is 300 microns. It further grows in size in the thoracic muscles of the mosquito and reaches to 3rd stage (L3) or infective stage. The average size of the 3rd stage larva (L3) is 1500 microns and it has 2 or 3 sub-terminal caudal papillae. The 3rd stage larva (L3) after full development in the thoracic muscles of the mosquito moves to its proboscis and becomes ready for infection. The 3rd stage (L3) development occurs in 3-5 days (Figure-8, L3 worms emerging from the proboscis of the mosquito). There may be one or more infective larvae in one mosquito. Thus, the complete development from microfilaria to the infective larva in the mosquito is completed in 10-15 days. Such vector mosquitoes are known as infective mosquitoes. When the infective mosquito bites a man, the 3rd stage larvae are deposited at the site of the puncture on the skin.

**Figure- 8: L3 worms emerging from the proboscis of the mosquito (WHO, 2013)**

**In human body**

The infective larvae deposited at the site of the punctured skin, make an entry in the human body and reach the lymphatic channels. They settle down at inguinal, scrotal or abdominal lymphatics, where they begin to grow into adult form. The adult form is sexually mature. The male fertilizes the female worm and the female gives birth to embryos, which are called microfilariae. The size of the microfilariae is nearly 300 microns and the normal life span varies from 15-70 days. They pass through the thoracic or the right lymphatic duct to the venous system and pulmonary capillaries and then to the peripheral circulation. The microfilariae circulate in the peripheral blood only at night, this phenomenon is called nocturnal periodicity. The nocturnal periodicity is presumed to be associated with the feeding habit of the vector mosquito (Table- 7).

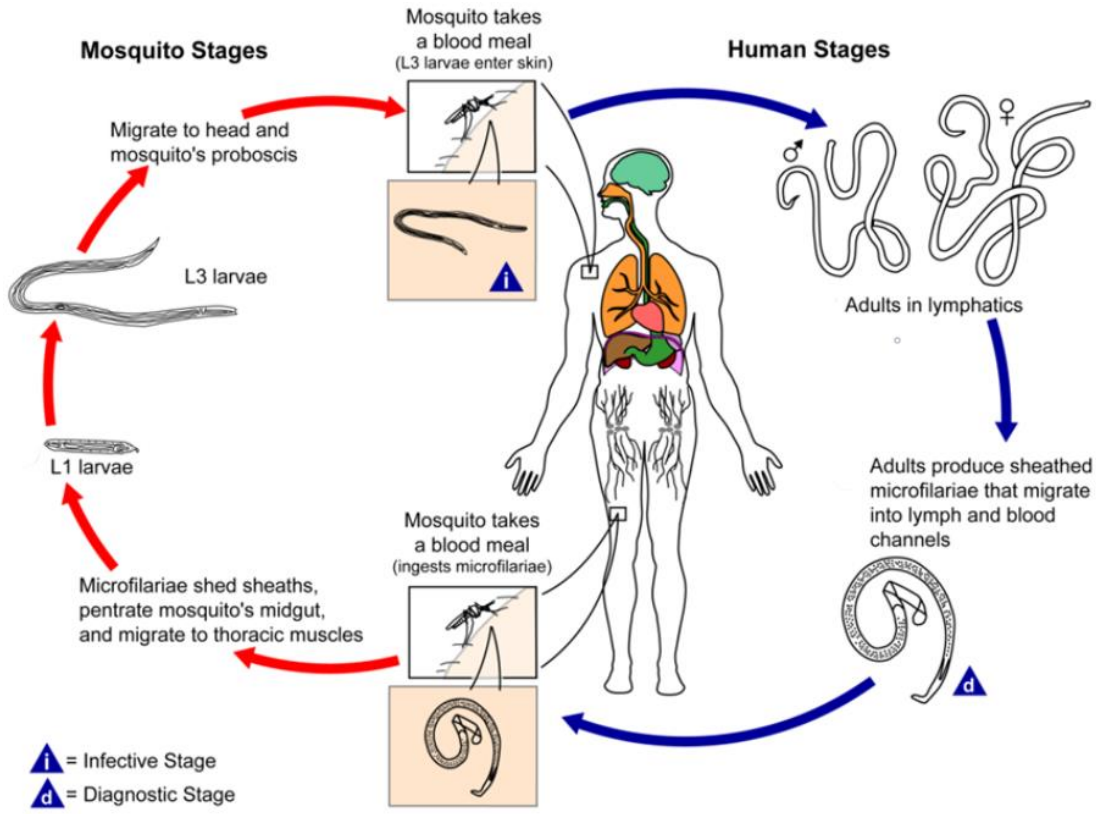



**Figure- 9: Transmission cycle of lymphatic filariasis (CDC)**

### 2.2.4 Epidemiology

*Wuchereria bancrofti* is most widely spread and responsible for more than 90% of infections. *Brugia malayi* is found in several Asian countries, whereas *B. timori* is only found in Indonesia. In recent years, the incidence of filariasis has been showing an increasing trend. This is mainly due to unplanned urbanization, rapid industrialization, creating more mosquitogenic conditions and frequent movement of people between endemic and non-endemic areas. The *W. bancrofti* infection is both urban and rural, while *B. malayi* is mainly confined to rural areas because of the peculiar breeding habits of the vector. The latter infection has been showing a decreasing trend recently. Both the infections in mainland India exhibit nocturnal periodicity necessitating night blood surveys for screening of microfilaria (*mf*) carriers.

Temperature and relative humidity play a pivotal role in the endemicity of the disease. In high transmission areas, the temperature varies between 21°C to 32°C with a relative humidity of 70%. Besides macroclimate, microclimate also has a direct bearing on the longevity of the vector and the extrinsic cycle of the parasite. Development in the mosquitoes (intermediate host) would be inhibited if temperature is below 15°C while the temperature above 33°C is

known to be detrimental. In heavy monsoon seasons, most of the breeding is either washed away or the breeding sources are greatly diluted of the organic pollution. Mosquito densities are built up during the post-monsoon period in many areas. Transmission intensity varies greatly in different geographical regions depending upon many factors. Acute filarial attacks have been found to occur more frequently at the end of the monsoon. Areas showing optimum temperature and relative humidity during most part of the year have been found to be highly endemic.

Lymphatic filariasis is transmitted when microfilariae circulating in the blood of an infected human are taken up in a blood-meal by a mosquito, where the microfilariae develop into infective larval stages. When the mosquito bites a human, the infective larvae migrate into the lymph system and adult worms develop. Therefore, transmission can be interrupted by killing adult worms, killing microfilariae or by killing mosquito vectors or by preventing them from biting humans. As none of the drugs used in mass administration kill all adult worms, the aims of the current global strategy for interrupting transmission are (i) to reduce, using a combination of two microfilaricides, the density of microfilariae in the blood of infected people to a level at which they can no longer be transmitted by mosquito vectors to a new human host; and (ii) to reduce the prevalence of microfilariae in the community to a level at which transmission can no longer be sustained, even in the presence of mosquito vectors. These objectives are achieved by annual mass drug administration for at least 5 years, which is generally considered to be the reproductive lifespan of an adult worm in an infected human host. While mass drug administration is the mainstay of lymphatic filariasis elimination, it is complicated biologically and logistically and by insufficient resources in some areas. Vector control could play a complementary role in lymphatic filariasis elimination (WHO, Global Programme to eliminate Lymphatic Filariasis, 2020)

### 2.2.5 Burden in India

Lymphatic filariasis is widely prevalent and is a serious public health problem in India. According to the estimates in 1994, India alone accounts for 43% of the global infected population (WHO, 1994). In 1997, WHO and its member states committed to eliminate LF as a public health problem by 2020 through the world health assembly resolution. The Global Alliance to Eliminate Lymphatic Filariasis (GAELF) was formed in 2000 with the sole purpose of supporting the Global Programme to Eliminate Lymphatic Filariasis and sets its two goals *i. e.* 1. The elimination of lymphatic filariasis as a public health problem by 2020

and 2. The alleviation of physical, social and economic hardship in individuals who have lymphatic filariasis induced disability. The National Health Policy (2002) has set the goal of elimination of lymphatic filariasis in India by 2015, later extended to 2021 (http://nvbdcp.gov.in).

Lymphatic filariasis does not directly cause death, but its chronic manifestations are an important cause of disability and reduction in quality of life. Hydrocele and lymphoedema are associated with impaired mobility and social activity, reduced work capacity, sexual dysfunction, severe psycho-social problems, stigma and bad marital prospects. In pursuit of the goals, the Government of India launched nationwide Mass drug Administration (MDA) in 2004 in 202 districts of 20 states and UTs with a single dose of Diethylcarbamazine citrate (DEC) in endemic areas as well as home-based morbidity management, scaling up hydrocelectomies in hospitals and CHCs, afterwards in the year 2007 Diethylcarbamazine citrate + Albendazole (DEC+ALB) combination therapy implemented and from 2018 Triple Drug Therapy (IDA) i.e. DEC + Albendazole + Ivermectin is launched initially in five selected districts viz. Arwal, (Bihar), Simdega (Jharkhand), Varanasi (Uttar Pradesh), Nagpur (Maharashtra) and Yadgir (Karnataka). Since the elimination target is approaching first all the left-out districts, which are yet to achieve elimination will be brought under IDA. The GPELF-MDA is one of the good opportunities to implement LF control measures in the entire country to eliminate this disease.

The population coverage during MDA has improved from 73% in 2004 to 87.33% in 2019. The number of districts was upscaled and in 2007 all the 250 (now 256 due to bifurcation) known LF endemic districts were brought under MDA. It is reported that 257 districts (1 district included in 2019) have been brought under MDA where about 650 million population are at risk of Lymphatic Filariasis in the country and out of that about 500 million populations are eligible for MDA in the country (http://nvbdcp.gov.in). In 2013 validation started through Transmission Assessment Survey (TAS), which is conducted in 43 districts during 2021 (http:// nvbdcp.gov.in VL/LF update 2022).

### 2.2.6 Global burden

Lymphatic filariasis is widely distributed in South-east Asia, Africa, the South Pacific region, Eastern Mediterranean and South America. In several countries, LF was a major public health problem and one of the leading causes of disability. During 2020, 863 million people in 50 countries worldwide remain threatened by lymphatic filariasis and require preventive

chemotherapy to stop the spread of this parasitic infection (https://www.who.int/news-room/fact-sheets/detail/lymphatic-filariasis 2022). The global baseline estimate of people affected by lymphatic filariasis was 25 million men with hydrocele and over 15 million people with lymphoedema. At least 36 million people remain with these chronic disease manifestations.

Several countries encouraged by Global Program for Elimination of Lymphatic Filariasis (GPELF) for steady progress over the years. The GPELF has delivered over 8.2 billion cumulative treatments to more than 923 million people since 2000. In 2019, 538.1 million people were treated for lymphatic filariasis (LF) in 38 countries that implemented mass drug administration (MDA) for populations at risk of the disease, as recommended by the World Health Organization (WHO). Seventeen countries achieved the criteria for the elimination of LF as a public health problem.

WHO will accelerate work to achieve this target by 2030 despite setbacks due to COVID-19. New global estimates suggest a 74% reduction in the number of infected people since the start of GPELF. The new, ambitious targets for 2030 are that 80% of endemic countries have met the criteria for validation of elimination as a public health problem, with the remaining 20% under post-treatment surveillance, meaning that MDA will no longer be required (WHO, 2020).

## 2.3 JAPANESE ENCEPHALITIS (JE)

### 2.3.1 Introduction

Japanese Encephalitis (JE) is a mosquito borne zoonotic viral disease. Japanese Encephalitis Virus (JEV) is a flavivirus (family Flaviviridae) and maintained in a transmission cycle between the mosquito vectors and vertebrate hosts, mainly Ardeid birds (herons and egrets are considered natural reservoirs), pigs (amplifying hosts), and possibly bats (Van den, 2022). JEV is the most important cause of viral encephalitis in Asia and is transmitted to humans through the bites of infected mosquitoes of the *Culex* species (mainly *Culex tritaeniorhynchus*).

The first case of JE was documented in 1871 in Japan. Most JEV infections are mild (fever and headache) or without apparent symptoms, but approximately 1 in 250 infections results in severe clinical illness. The incubation period is between 4-14 days. In children, gastrointestinal pain and vomiting may be the dominant initial symptoms. Severe disease is characterized by rapid onset of high fever, headache, neck stiffness, disorientation, coma, seizures, spastic paralysis and ultimately death (WHO, 2019). JE affects the central nervous system and can cause severe complications, seizures and even death. The case fatality rate of this disease is very high and those who survive may suffer with various degrees of neurological sequelae. Children suffer the highest attack rates because of a lack of cumulative immunity due to natural infection (NVBDCP, 2009). Most adults in endemic countries have natural immunity after childhood infection, but individuals of any age may be affected. The annual incidence of the clinical disease varies both across and within endemic countries, ranging from <1 to >10 per 1,00,000 population or higher during outbreaks (WHO, 2019).

### 2.3.2 Causative agent and vector

Japanese encephalitis virus (JEV) is a member of the family flaviviridae, genus *Flavivirus*. JE is an infection of the Central Nervous System (CNS) caused by a *Flavivirus*. This virus primarily affects animals, and man is an accidental host and does not play a role in JE transmission. The vertebrate hosts produce high viremia, allowing mosquitoes to become infected when taking a blood meal. JEV is the most important cause of epidemic encephalitis worldwide. In India, JE virus has been isolated from seventeen mosquito species viz. four *Anopleles spp*., ten *Culex spp.* and three *Mansonia spp*. (NVBDCP, 2014; Samuel et al., 2000) and mainly *Culex vishnui* group (*Culex tritaeniorhynchus, Cx. vishnui* and *Cx.*

*pseudovishnui*), *Cx. gelidus* and *Cx. fuscocephala* are the prominent vectors in different parts of India (Table- 8).

**Table- 8: State-wise prevalence of JEV infection among mosquitos**

| Sl. No. | Species | States |
|---|---|---|
| 1 | *Cx. tritaeniorhynchus* | Tamil Nadu, Karnataka, Kerala, UP, Haryana |
| 2 | *Cx. vishnui* | Tamil Nadu, Karnataka, West Bengal |
| 3 | *Cx. pseudovishnui* | Karnataka, Goa |
| 4 | *Cx. bitaeniorhynchus* | Karnataka, West Bengal |
| 5 | *Cx. epidesmus* | West Bengal |
| 6 | *Cx. fuscocephala* | Tamil Nadu, Karnataka |
| 7 | *Cx. gelidus* | Tamil Nadu, Karnataka |
| 8 | *Cx. quinquefasciatus* | Karnataka |
| 9 | *Cx. whitmorei* | Tamil Nadu, Karnataka, Andhra Pradesh, West Bengal |
| 10 | *Cx. infula* | Tamil Nadu |
| 11 | *An. barbirostris* | West Bengal |
| 12 | *An. paeditaeniatus* | Karnataka |
| 13 | *An. subpictus* | Tamil Nadu, Karnataka, Kerala |
| 14 | *An. hyrcanus* | Assam, West Bengal |
| 15 | *Ma. annulifera* | Kerala, Assam |
| 16 | *Ma. indiana* | Kerala |
| 17 | *Ma. uniformis* | Karnataka, Kerala |

### 2.3.3 Transmission

The virus is maintained in a cycle between mosquitoes and vertebrate hosts, primarily pigs and water birds. Humans are incidental or dead-end hosts. JE virus transmission occurs primarily in rural agricultural areas, often associated with rice production and flooding irrigation. In some areas of Asia, these conditions can occur near urban centers. In temperate areas of Asia, *Culex vishnui* subgroup is a very common vector mosquito. These vectors are primarily outdoor resting in vegetation and other shaded places but in summer may also rest indoors. They are principally cattle feeders, though human and pig (Amplifying host) feeding are also recorded in some areas.

Humans become infected when they are bitten by mosquitoes infected with JE virus. The JE natural cycle is maintained in these mosquitoes, vertebrate animals and wading birds such as herons, egrets etc. (Figure- 10). However, when the conditions are favorable, humans are subject to mosquito bites and infected incidentally. These mosquito vectors generally breed in ground water habitats, particularly in paddy fields, irrigation canals, ground pools and shallow ditches. Mosquito breeding increases during rainy seasons

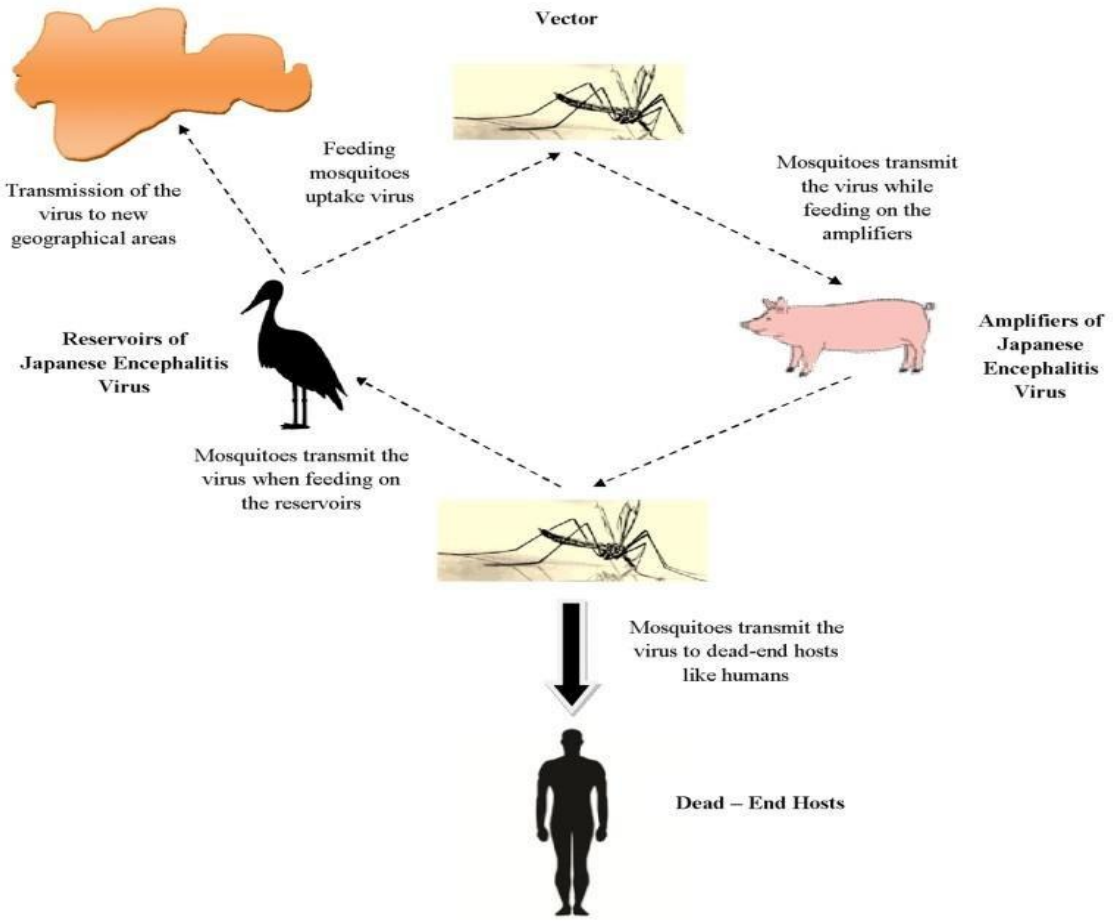



**Figure- 10: Transmission cycle of JEV (Ghana et al., 2019)**

### 2.3.4 Epidemiology

Two epidemiological patterns of JE are recognized: epidemic and endemic. Epidemic patterns observed mainly in northern areas (Bangladesh, Bhutan, People's Republic of China, Taiwan, Japan, South Korea, North Korea, Nepal, northern Vietnam, North-Eastern states of India, northern Thailand, Pakistan, and Russia) demonstrate typical seasonal characteristics with occasional outbreaks. Endemic patterns found in southern areas (Australia, Burma, Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Papua New Guinea, Philippines, Singapore, southern Vietnam, southern Thailand, southern India, Sri Lanka, and Timor-

Leste) occur sporadically throughout the year (Wang and Liang, 2015). JE transmission intensifies during the rainy season when vector population increases.

The spread of JEV in newer areas has been correlated with agricultural development and intensive rice cultivation supported by irrigation programs. The disease is predominantly found in rural and peri-urban settings, where humans live in closer proximity to these vertebrate hosts. JE virus transmission is seasonal, human disease usually peaks after the rainy season. In the subtropics and tropics, transmission can occur year-round, often with a peak during the rainy season.

### 2.3.5 Burden in India

The first case of Japanese Encephalitis was reported in India in 1955 from Vellore, Tamil Nadu (Reuben and Gajanana, 1997), and the first major JE outbreak was reported in 1973 from the Burdwan district of West Bengal. In Uttar Pradesh, the first major JE epidemic occurred in Gorakhpur in 1978, with 1,002 cases and 287 deaths reported. JE has been reported from 171 districts of 19 States in India.

In UP, the first JE/AES outbreak occurred in 1978, which caused more than 3,500 cases and 1,100 deaths (mortality = 31.4%) (Srivastava et al., 2022). Between 1978 and 1987, UP reported 9,299 suspected JE/AES cases and 3,103 deaths. Afterwards, extensive and recurrent outbreaks occurred in the years 1988 and 2005 in the state. AES outbreak in 2005 was the most devastating epidemic in UP, which caused more than 5,000 cases and 1,300 deaths, respectively, followed by further massive outbreaks in 2006 and 2007 with more than 5,000 cases and 1,173 deaths (Kumari and Joshi, 2012). During the years 2008–2018, UP reported 36,509 AES cases and 5,700 deaths (Singh et al., 2020).

Data regarding the number of cases and number of deaths reported during year 2015 to 2021 is mentioned in Figure-11. Highest number of cases and deaths were reported in the year 2019 since 2015. Assam is the most affected state with the highest number of cases and deaths after which comes Uttar Pradesh and then West Bengal at second and third position respectively (http://nvbdcp.gov.in).

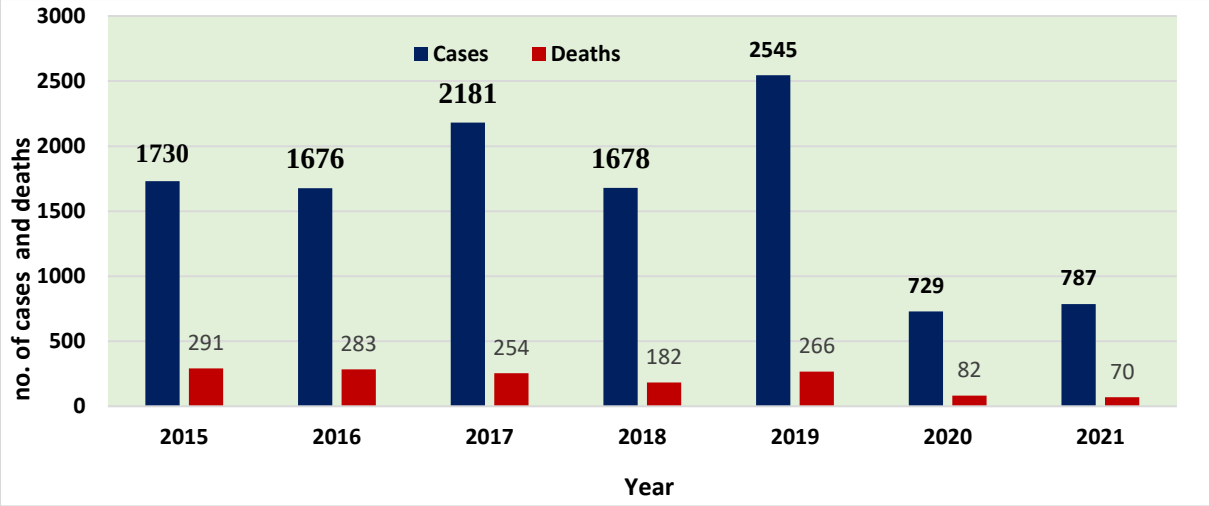



**Figure- 11: JE situation in India during 2014-2021 (Source: NCVBDC)**

### 2.3.6 Global burden

Japanese Encephalitis (JE) occurs over a wide area, extending from the south eastern part of the USSR, through Korea, Japan and China, as far as Indonesia in the south, and India to the west. During the past two decades, the epidemiological pattern and distribution of the disease have changed, and incidence has subsided in Japan, Korea and China, but has increased and spread in parts of Bangladesh, Burma, India, Nepal, Thailand and Vietnam. Reasons may include the promotion of pig breeding, etc.

Epidemics of encephalitis were described in Japan from the 1870s onwards. JEV was first isolated in 1935 and has subsequently been found across most of Asia. The origins of the virus are uncertain, but phylogenetic comparisons with other *flavivirus* suggest it evolved from an African ancestral virus, perhaps as recently as a few centuries ago. Four genotypes of the virus have been identified, genotype I include isolates from northern Thailand, Cambodia, and Korea, genotype II includes isolates from southern Thailand, Malaysia, Indonesia, and Northern Australia, genotype III includes isolates from mostly temperate regions of Asia, including Japan, China, Taiwan, the Philippines, and the Asian subcontinent, and genotype IV includes isolates from Indonesia. 24 countries in the WHO South-East Asia and Western Pacific regions have JEV transmission risk, which includes more than 3 billion people. In most temperate areas of Asia, JEV is transmitted mainly during the warm season, when large epidemics can occur. In the tropics and subtropics, transmission can occur year-round but often intensifies during the rainy season and pre-harvest period in rice-cultivating regions (WHO, 2019).

## 2.4 DENGUE

### 2.4.1 Introduction

Dengue is a mosquito-borne viral infection, the most rapidly spreading and a major public health concern throughout the tropical and subtropical regions of the world. Dengue has been identified as one of the 17 neglected tropical diseases by the World Health Organization (2010). Dengue occurrence is very common after the rainy season. It is causing a severe flu-like illness and, sometimes causes a potentially lethal complication called severe dengue. The incidence of dengue has increased 30-fold over the last 50 years. Up to 50-100 million infections are now estimated to occur annually in over 100 endemic countries, putting almost half of the world's population at risk. Dengue Fever (DF), also known as breakbone fever, is a viral infection caused by the dengue virus that is transmitted through the bite of the infected *Aedes* mosquito. Dengue fever signs and symptoms comprise - the abrupt onset of high fever; severe frontal headache; pain behind the eyes (retro-orbital pain), which worsens with eye movement; muscle and joint pains; measles-like rashes over the chest and upper limbs; nausea and vomiting (http://nvbdcp.gov.in).

Dengue virus infection is usually self-limiting and mild, but can also result in severe diseases classified as dengue hemorrhagic fever/dengue shock syndrome or severe dengue as described in World Health Organization guidelines (WHO, 1997; WHO/TDR, 2009).

### 2.4.2 Causative agent and vector

The causative agent of dengue *i. e.* Dengue virus (DENV) belongs to the genus *Flavivirus*, family flaviviridae. The virus contains single-stranded RNA and is small in size (50 nm). There are four different serotypes of the dengue virus: DENV-1, DENV-2, DENV-3 and DENV-4. Infection with any one serotype confers lifelong immunity to that virus serotype, which means that in humans, one serotype produces lifelong immunity against re-infection but only temporary and partial immunity against the other serotypes. Subsequent infections (secondary infection) by other serotypes increase the risk of developing severe dengue (WHO, Dengue and severe, 2022).

*Aedes aegypti* is the primary vector and *Ae. albopictus* is secondary vector for transmission of dengue. *Ae. aegypti* has been mainly associated with dengue outbreaks in India. It is very efficient vector and can build up high transmission potential even at a low population level because of (i) restricted dispersal, and (ii) its day time biting habit where a female is

obligated to make repeated biting (split feeding) attempts for taking a single blood meal from one or more persons. *Ae. albopictus* has also been incriminated for dengue and chikungunya peripheral areas of rural and urban areas. *Ae. albopictus* is of an aggressive feeding nature without interruption. It can be considered as a secondary vector in sylvatic areas.

### 2.4.3 Transmission

Dengue viruses are transmitted to humans through the bite of an infected female *Aedes* mosquito. Most vector mosquitoes are anautogenous, which means that females require a vertebrate blood meal for egg production and development. Female *Aedes* mosquitoes bite humans and animals. After feeding on DENV-infected person, the virus replicates in the mosquito midgut, before it disseminates to secondary tissues, including the salivary glands. The time it takes from ingesting the virus to actual transmission to a new host is termed the extrinsic incubation period (EIP). The EIP takes about 8-12 days when the ambient temperature is between 25-28°C. The length of time required for this extrinsic incubation depends in part on environmental conditions, especially ambient temperature. Several factors can influence the dynamics of virus transmission- including environmental and climate factors, host-pathogen interactions and population immunological factors. Once infected, the mosquito is capable of transmitting the virus for the rest of its life (WHO, 2022 https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue#).

Mosquito once infected remains infected for life, transmitting the virus to susceptible individuals during probing and feeding. Infected female mosquitoes may also pass the virus to the next generation of mosquitoes by transovarial transmission, which is a mechanism by which infective female mosquitoes pass the virus to their offspring via their eggs. (Figure-12). Each female *Ae. aegypti* mosquito can lay multiple batches of eggs during its lifetime and often takes several blood meals before laying a batch of eggs.

While taking a blood meal, an infected female mosquito injects its saliva into the human host to prevent the host's blood from clotting and to ease feeding. As the virus remains in saliva, this injection of saliva infects the host with the dengue virus. The virus circulates in the blood of infected humans when they have a fever and uninfected mosquitoes may acquire the virus if they feed on such an individual at the viremic stage. Then virus develops inside the mosquito before it can be transmitted to other healthy humans during subsequent probing or feeding.

Dengue fever isn't contagious directly from one person to another like the flu. In rare events, dengue can be transmitted during organ transplantations or blood transfusions from infected donors. There is also evidence that an infected pregnant mother can transmit the dengue virus to her fetus. Despite these rare events, the majority of dengue infections are transmitted by mosquito bites.

Dengue virus transmission likely originated from sylvatic cycles maintained between susceptible non-human primates and *Aedes* mosquitoes in the forests of Asia. Spillover of sylvatic dengue virus can occur in both rural and urban areas as zones of emergence. Given the adaptability of the sylvatic virus for the human host and documented past infections that resulted in severe clinical manifestations, this can potentially sustain the natural horizontal human-to-human transmission via *Aedes aegypti* and *Aedes albopictus* mosquitoes. Humans are known to be the main reservoir host in maintaining urban epidemic cycles of dengue

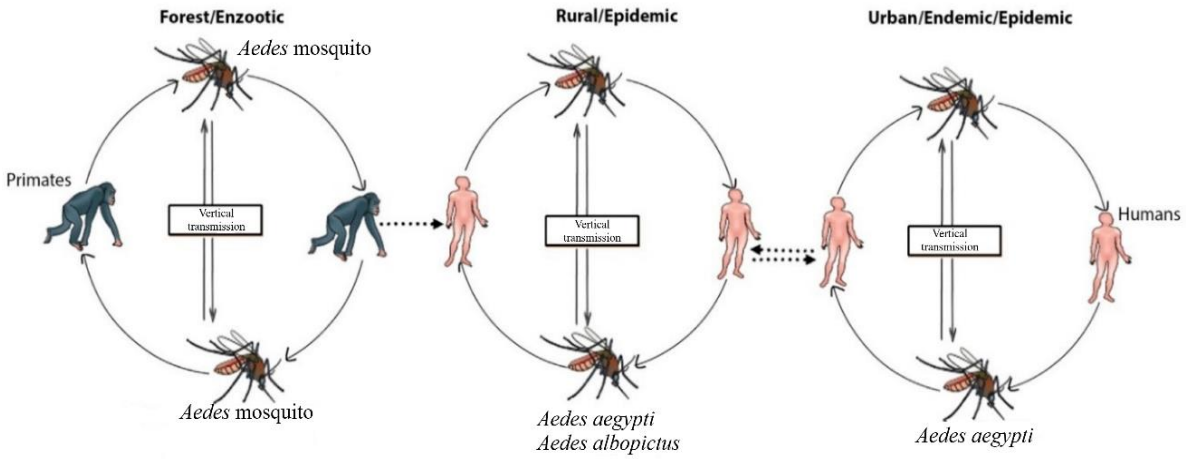



**Figure- 12: Dengue transmission cycle (Ahammad et al., 2019)**

Local transmission may be established if DENV-infected travellers bring the virus to new locations and there is a presence of susceptible vectors.

### 2.4.4 Epidemiology

In recent decades, the incidence of dengue has risen significantly around the world. Dengue epidemiology is a dynamic phenomenon that relies on a complex relationship between epidemiological factors, *i.e.*, host (man and mosquito), virus and environmental (abiotic and biotic factors); the nature of the relationship between these factors ultimately determines the intensification of transmission within an area. During inter-epidemic times, dengue transmission remains low due to extreme of temperature with low relative humidity but when

the environment becomes ideal for vectors during monsoons, transmission reaches its peak. Dengue transmission is usually associated with periods of higher rainfall in most endemic countries like India. Seasonal variation reported from 2016 to 2021 is depicted in the following (Figure-13). In areas where water storage containers are not influenced by rainfall, however, other factors such as higher humidity and moderate ambient temperatures associated with the rainy season increase survival of infected mosquitoes, thus increasing the chances of secondary transmission to other persons.

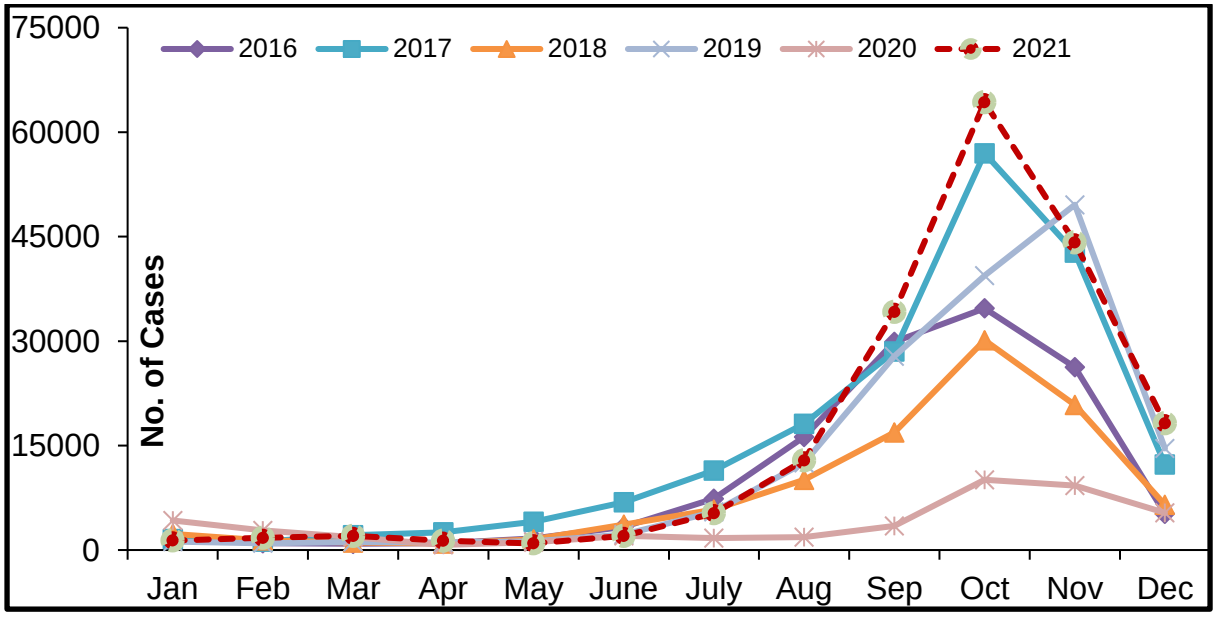



**Figure-13: Seasonal variation of Dengue in India (NCVBDC)**

### 2.4.5 Burden in India

The burden of dengue in India is very complex and has changed considerably in terms of prevalent strains, affected geographical locations and severity of disease over the past six decades. The first evidence of the occurrence of dengue fever in the country was reported in 1956 from the Vellore district in Tamil Nadu. The first Dengue Hemorrhagic Fever (DHF) outbreak occurred in Kolkata, West Bengal in 1963 (Baruah et al., 2011 and 2014).

All States/UTs reported dengue cases except Lakshadweep and Ladakh during the last two decades. Recurring outbreaks of dengue have been reported from various states/UTs for e.g., Andhra Pradesh, Chandigarh, Delhi, Goa, Haryana, Gujarat, Karnataka, Kerala, Maharashtra, Rajasthan, Uttar Pradesh, Puducherry, Punjab, Tamil Nadu, Telangana and West Bengal. In 1996, one of the most severe outbreaks occurred in Delhi with reporting of 10,252 cases and

423 deaths (16,517 cases and 545 deaths from country) (Figure-14 & 15). Most of the Indian states have been classified as having frequent or continuous risk of dengue transmission.

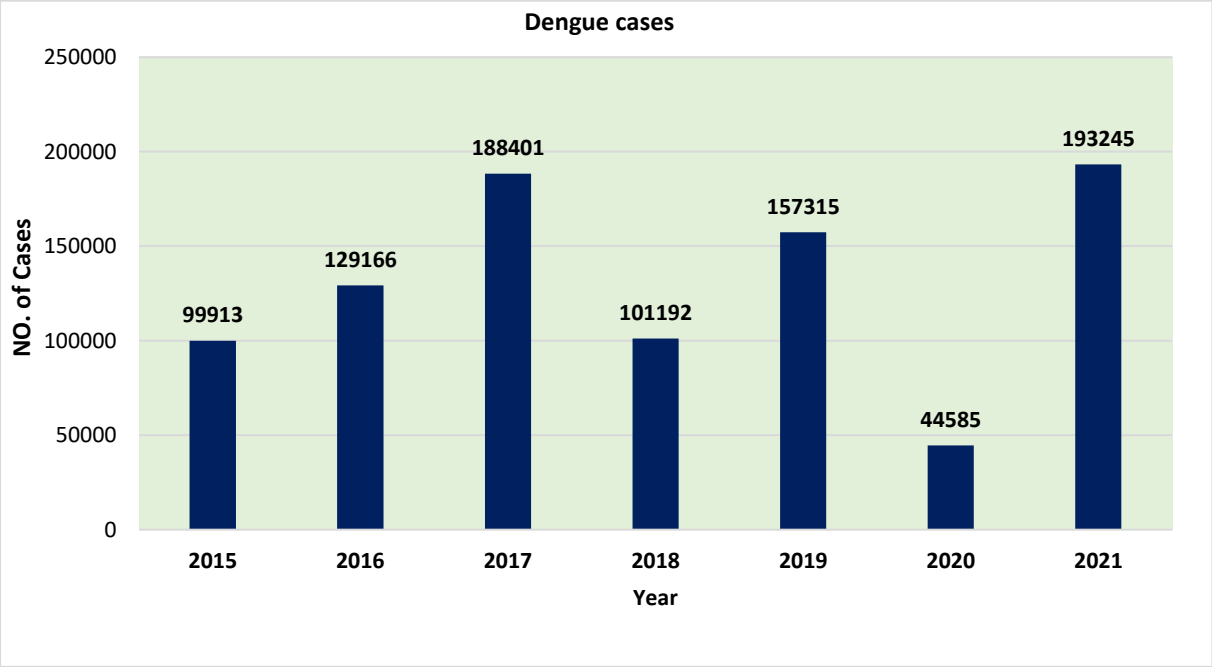



**Figure- 14: Dengue cases in India during 2015-2021**

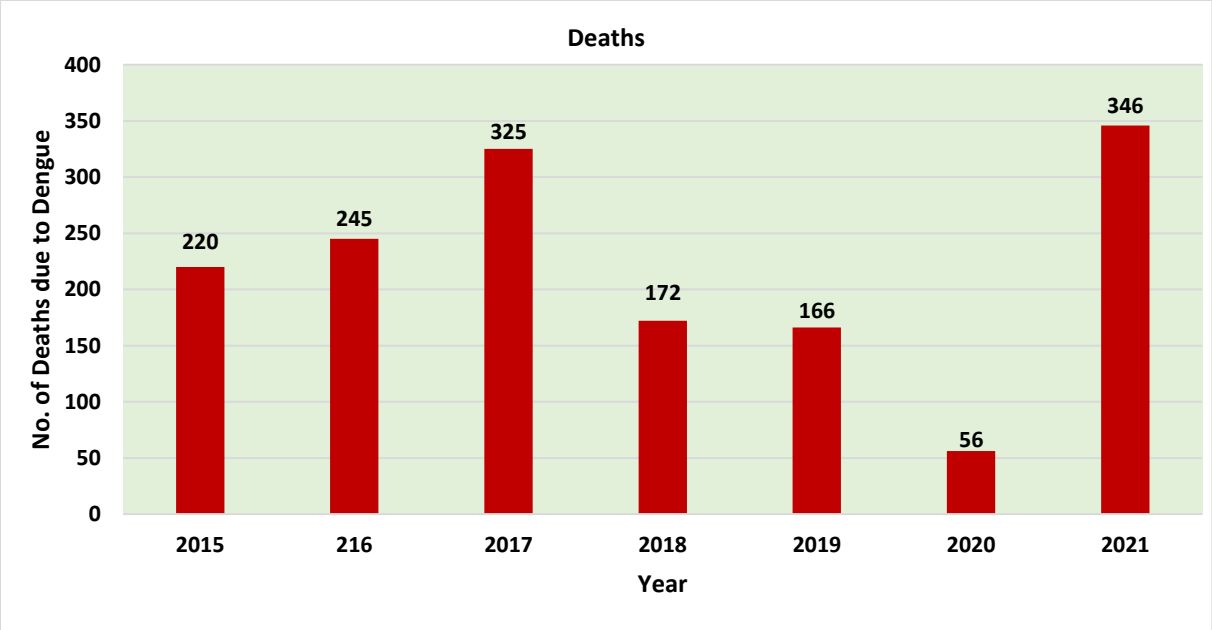



**Figure- 15: Dengue deaths in India during 2015-2021**

### 2.4.6 Global burden

Around the world, in recent decades the incidence of dengue has grown dramatically. It is estimated that, about 390 million dengue virus infections are occurring per year (95% credible interval 284–528 million), of which 96 million (67-136 million) manifest clinically (with any severity of disease), while in another study on the prevalence of dengue estimated that 3.9 billion people are at risk of infection with dengue viruses. Despite a risk of infection existing in 129 countries, 70% of the actual burden is in Asia. The number of dengue cases reported to WHO increased over 8-fold over the last two decades, from 505,430 cases in 2000 to over 2.4 million in 2010, and 4.2 million in 2019. Reported deaths between the years 2000 and 2015 increased from 960 to 4032, affecting mostly the younger age group. The total number of cases decreased during the years 2020 and 2021, as well as for reported deaths. However, the data is not yet complete and COVID-19 pandemic might have also hampered case reporting in several countries. The largest number of dengue cases ever reported globally was in 2019. All regions were affected, and dengue transmission was recorded in Afghanistan for the first time (WHO, 2022). In 2020, dengue affected several countries, with reports of increases in the numbers of cases in Bangladesh, Brazil, Cook Islands, Ecuador, India, Indonesia, Maldives, Mauritania, Mayotte (Fr), Nepal, Singapore, Sri Lanka, Sudan, Thailand, Timor-Leste and Yemen. Dengue continues to affect Brazil, India, Vietnam, the Philippines, the Cook Islands, Colombia, Fiji, Kenya, Paraguay, Peru and, the Reunion islands, in 2021 (WHO, 2022).

## 2.5 CHIKUNGUNYA

### 2.5.1 Introduction

Chikungunya (CHIK) is a viral infection caused by the Chikungunya virus (CHIKV). It is transmitted to humans by the same infected mosquitoes, which spread Dengue and Zika virus. Chikungunya virus disease or chikungunya fever, is a debilitating, but non-fatal, viral illness, a re-emerging mosquito borne disease, a relatively rare and benign form of viral fever. Chikungunya viral disease was first described during an outbreak in southern Tanzania in 1952 (WHO, 2009).

Symptoms of infection generally last for 3-7 days from infected mosquito bite. After an incubation period of 4-7 days, there is a sudden onset of flu-like symptoms including fever, chills, headache, nausea, vomiting, and severe joint pain (arthralgia). The name Chikungunya, a word from the Kimakonde language means "that which bends up", because of the stooped posture and rigid gait of infected individuals. Frequently, the infection causes no symptoms, especially in children. While recovery from chikungunya is the expected outcome, convalescence can be prolonged and persistent joint pain may require analgesic (pain medication) and long-term anti-inflammatory therapy. Infection appears to confer lasting immunity (NCVBDC). There is no vaccine to prevent or medicine to treat Chikungunya virus infection.

### 2.5.2 Causative agent and vector

Chikungunya virus (CHIKV) is an *Alphavirus* that belongs to the Togoviridae Family. Chikungunya virus has a single-stranded, positive-sense RNA genome. Female mosquito, mainly *Aedes aegypti* and *Aedes albopictus* are acting as vectors for transmission of Chikungunya virus to people. They are day biters. *Aedes* mosquito takes multiple feeds during the day and which would also result in outbreaks. People are the primary host of Chikungunya virus during epidemic periods.

### 2.5.3 Transmission

Infected vector mosquitoes transmit Chikungunya virus among humans. When a freshly emerged/ uninfected mosquito feeds upon someone who has the virus circulating in their blood (viremic person) can pick up the virus while ingesting the blood. The virus then undergoes a period of replication in the mosquito, before which time it can then be

transmitted back to a new host when the mosquito next feeds. The virus again begins to replicate in this newly infected person and amplifies to high concentrations. If a mosquito feeds on them during the time they have the virus circulating in their blood, the mosquito can pick up the virus, and the transmission cycle begins again.

Within the mosquito, the virus replicates in the mosquito midgut. It then disseminates to secondary tissues, including the salivary glands. CHIKV can be transmitted to a new host more quickly than other mosquito-borne viruses; laboratory experiments have demonstrated virus can be detected in saliva as early as 2-3 days after the blood meal. This suggests that the complete transmission cycle from human to mosquito, and back to humans can occur in well under a week. Once infected, the mosquito is believed to be capable of transmitting the virus for the rest of its life.

*Aedes aegypti* and *Aedes albopictus* can also transmit other mosquito-borne viruses, including Dengue and Zika fever viruses. Both species are found biting outdoors, but *Ae. aegypti* will also readily feed indoors.

High vector density in the post-monsoon season accentuates virus transmission. In Asia, the virus appears to be maintained in an urban human-mosquito-human transmission cycle with *Ae. aegypti* and *Ae. albopictus* while the CHIK virus transmission in Africa involves a sylvatic cycle, primarily with *Ae. furcifer* and *Ae. africanus,* as the vectors (WHO, 2009). The mosquitoes generally acquire the virus while feeding on the blood of an infected person (Figure- 16). After virus incubation for 2-12 days, which is usually 3-7 days, an infected mosquito is capable of transmitting the virus for the rest of its life during probing and blood feeding.

Infected humans are the main carriers and multipliers of the virus and serve as a source of the virus for uninfected mosquitoes. The virus circulates in the blood of infected humans, at approximately the same time that they have chikungunya fever. *Aedes* mosquitoes may acquire the virus when they feed on an individual during this period.

Chikungunya transmission is also related to rainfall and temperature. It has been observed during the period of monsoon and post-monsoon, there is an upsurge in the cases because the population of the vector fluctuates with rainfall. Eggs of these vectors can sustain desiccation for more than a year, helping the virus to remain in nature for long periods and cause outbreaks.

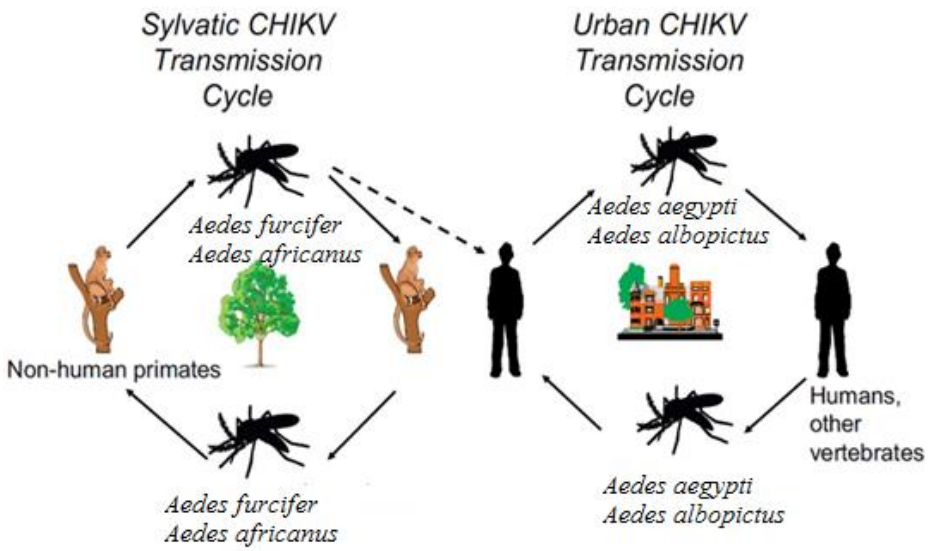



**Figure- 16: Chikungunya transmission cycle (CDC)**

Flight range of these vector mosquitoes are less making the outbreak to occur in clusters, especially in congested localities.

### 2.5.4 Epidemiology

Chikungunya likely originated in Africa, where the virus is spread through a sylvatic cycle in which the virus largely resides in other primates in between human outbreaks. The subsequent outbreak occurred in Africa and Asia, many of them affecting small or rural communities. Chikungunya virus (CHIKV), a reemerging arbovirus, causes a crippling musculoskeletal inflammatory disease in humans. It is responsible for periodic and explosive outbreaks of a febrile disease that is characterized by severe and sometimes prolonged polyarthritis. Epidemic of fever, rash, and arthritis resembling CHIK was reported as early as the 1770s. Chikungunya virus is maintained in the human population by a human-mosquito-human transmission cycle. Chikungunya fever epidemics display cyclical and seasonal trends. There is an inter-epidemic period of 4-8 years (sometimes as long as 20 years). Outbreaks are most likely to occur in post-monsoon period when the vector density is very high and accentuates the transmission. Human beings serve as the Chikungunya virus reservoir during the epidemic period. During inter-epidemic periods, some vertebrates have been implicated as reservoirs in African regions. These include monkeys, rodents and birds. However, the reservoir status in South-East Asia Region has not been documented yet.

Unlike dengue, a characteristic feature of CHIKV disease is a recurring musculoskeletal disease primarily affecting the peripheral joints that can persist for months to years after acute infection. CHIKV disease is often self-limiting and has a low fatality rate (~0.1%) , but manifestations of CHIKV infection that lead to acute and chronic disability have considerable implications, including a substantial impact on the quality of life for infected patients as well as considerable economic and community consequences. CHIKV is a virus for which four major lineages have been proposed: Asia Urban (AUL), Indian Ocean (IOL), East, Central and South Africa (ECSA) and West Arica (WA) (Schneider et al., 2019)

### 2.5.5 Burden in India

The first significant urban outbreaks of chikungunya were reported during the last millennium viz. 1963 (Kolkata), 1965 (Puducherry and Chennai in Tamil Nadu, Rajahmundry, Vishakhapatnam and Kakinada in Andhra Pradesh; Sagar in Madhya Pradesh; Nagpur in Maharashtra). After the outbreak of chikungunya infection in India in 1973 in Barshi, Solapur district, Maharashtra state, the activity of CHIKV appeared to decline and no outbreak was reported from India until 2005. The outbreak started at the end of the year 2005 when cases of suspected fever were reported from some parts of Andhra Pradesh and Karnataka. Initially, the disease were thought to be dengue.

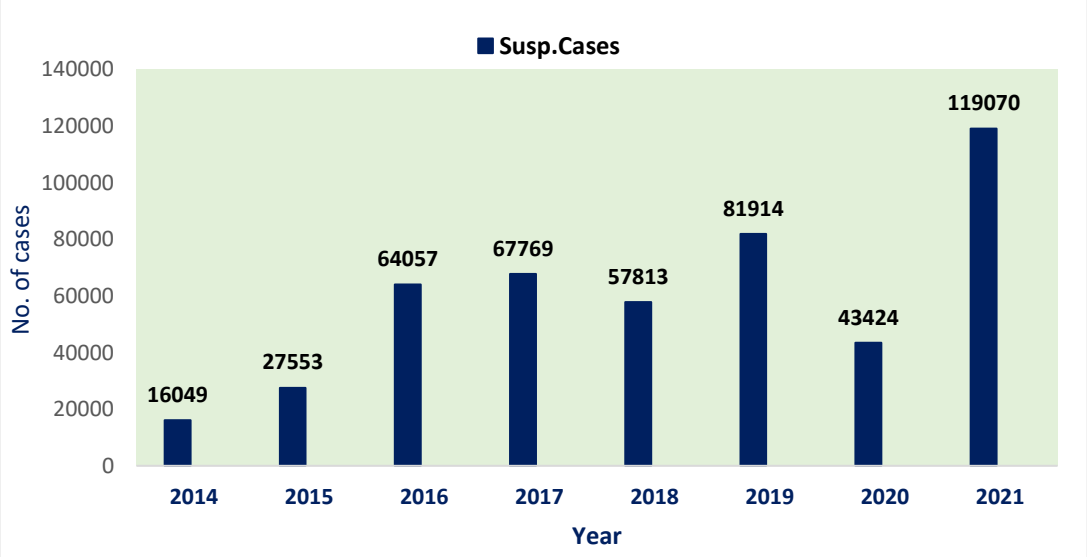



**Figure- 17: Chikungunya situation in India during 2014-2021 (NCVBDC)**

Subsequently, World Health Organization also confirmed the re-occurrence of chikungunya fever in India having an attack rate of 4-45% (WHO). After a quiescence of three decades, chikungunya appeared in unprecedented magnitude in many parts of the

country again in early 2006, with 1.39 million suspected cases reported from 16 states. Cases were also reported in subsequent years (Nagpal et al., 2012). Presently, Chikungunya is endemic in 32 States/UTs in the country. The clinically suspected Chikungunya cases reported from 2014 to 2021 are shown in Figure- 17 (NCVBDC).

### 2.5.6 Global burden

Chikungunya occurs in Africa, Asia and the Indian subcontinent. In Asia, CHIKV strains were isolated during large urban outbreaks in Bangkok, Thailand, in Kolkata city & Vellore, India during the 1960s and 1970s; Sri Lanka in 1969; Vietnam in 1975; Myanmar in 1975 and Indonesia in 1982. Starting in February 2005, a major outbreak of chikungunya occurred in islands of the Indian Ocean. Chikungunya virus has been associated with several outbreaks, localized mainly in tropical and subtropical regions of Africa and Southeast Asia. In 2004, Kenya experienced two major outbreaks of chikungunya. In February 2005, outbreaks were reported from the Indian Ocean islands, namely Comoros, Madagascar, Mayotte, Mauritius, Réunion Island and Seychelles. Attack rates peaked in these islands in 2006 and Réunion Island, it affected roughly one-third of the population (WHO, 2009). Several other countries in South-East Asia were also affected. Since 2005, India, Indonesia, Maldives, Myanmar and Thailand have reported over 1.9 million cases. In 2007 transmission was reported for the first time in Europe, in a localized outbreak in north-eastern Italy.

France confirmed 4 cases during 2014 of locally-acquired chikungunya infection in Montpellier. Chikungunya outbreak was reported from the Cook Islands and the Marshall Islands in 2015, while the number of cases in American Samoa, French Polynesia, Kiribati and Samoa has reduced. WHO responded to small outbreaks of chikungunya in late 2015 in the city of Dakar, Senegal.

In 2016, there was a total of 349936 suspected and 146914 laboratory-confirmed cases reported to the PAHO regional office, half the burden compared to the previous year. Countries reporting the most cases were Brazil (265000 suspected cases), Bolivia and Colombia (19000 suspected cases, respectively). Also, the first-time autochthonous transmission of chikungunya was reported in Argentina in 2016 following an outbreak of more than 1000 suspected cases. In the African region, Kenya reported an outbreak of chikungunya resulting in more than 1700 suspected cases. In 2017, Pakistan continued to respond to an outbreak, which started in 2016 (WHO, 2017).

## 2.6 ZIKA

### 2.6.1 Introduction

Zika virus (ZIKV) is an emerging mosquito-borne virus belonging to the genus *Flavivirus* of the Flaviviridae family. Zika virus was first isolated in 1947 from a rhesus monkey native to the Zika forest in Uganda and later on again isolated from *Aedes africanus* mosquitoes in 1948 during a project researching the yellow fever virus. It was later identified in humans in 1952 in Uganda and the United Republic of Tanzania. The name Zika was coined as the virus was first isolated from the Zika Forest of Uganda. Zika virus disease (ZVD) is similar to diseases caused by other flaviviruses, namely, Dengue virus (DENV), West Nile virus (WNV), Yellow Fever (YF), and Japanese encephalitis (JE). Infection with the Zika virus is also called Zika, Zika fever or Zika virus disease.

The most common clinical manifestations in patients with zika infections included high fever, malaise, stomach ache, diarrhoea, conjunctivitis, dizziness, and anorexia; other less frequent manifestations included myalgia, headache, retro-orbital pain, edema, and vomiting (Tova-Herrera et al., 2016). Zika virus infection during pregnancy is a cause of microcephaly (a congenital condition characterized by abnormal brain development and reduced brain tissue, which is the greatest concern with zika virus infection amongst pregnant women) and other congenital abnormalities in the developing fetus and newborn. Guillain–Barré syndrome (GBS) is one of the new complications and manifestations of ZIKV infection (Fontes, 2016), which is a serious and life-threatening neurological disorder that eventually results in respiratory failure characterized by progressive muscular weakness (Pithadia and Kakadia, 2010).

### 2.6.2 Causative agent and vector

Zika virus (ZIKV) is a *Flavivirus* and is transmitted among humans by mosquito bites. It consists of the lipid-enveloped, positive, single-stranded RNA genome, and seven non-structural proteins. The mosquito species namely *Aedes aegypti* is the primary vector and *Aedes albopictus* act as a potential vector in some setting for transmission of Zika virus disease. *Ae. aegypti* are day-biting mosquitoes while *Ae. albopictus* usually bite in the early morning and late afternoon. *Ae. aegypti* typically rest indoors and fly short distances up to 80 metres (WHO, 2016). *Aedes aegypti*, is reported as vector (Singh et al., 2019) from Indian subcontinent, widely prevalent and common in most of the urban areas on account of deficient water management, presence of non-degradable tyres and long-lasting plastic

containers as well as increasing urban agglomerations. Overhead tanks and ground water storage tanks are usually the primary habitats. The virus has been found in various mosquitoes of the *Aedes* genus, including *Aedes africanus, Ae. apicoargenteus, Ae. leuteocephalus, Ae. vitattus*, and *Ae. furcifer*.

### 2.6.3 Transmission

ZIKV is transmitted by *Aedes* mosquitoes, with humans representing the amplifying host (Duong, 2017). The role of the agent, vector, host and environment is crucial. The transmission of Zika virus can occur through either a vector or a non-vector transmission route. The main hosts for the virus are humans and non-human primates such as apes, monkeys and orangutans (Figure- 18).

#### 2.6.3.1 Vector transmission

Vector transmission of Zika virus occurs through the mosquito vector and is the predominant route for both human and non-human infection. It can occur through two distinct cycles, a sylvatic or an enzootic cycle in non-human primates and an urban-suburban cycle in the human population. The predominant human vectors are specifically the *Ae. aegypti* and *Ae. albopictus* mosquitoes. *Ae. aegypti* has a high vectorial capacity as it often lives in close association with humans and tends to bite multiple humans for a single blood meal. The urban-suburban cycle, thought to cause and sustain epidemics, exists within the human population in urban areas.

Humans serve as the carriers and source of the virus for the uninfected mosquito vector that predominantly bites during the day. In this cycle, the virus undergoes an intrinsic period of incubation for 4-5 days once inoculated into the human host after a blood meal, during which viral replication occurs in the skin dendritic cells, facilitating the transmission of the virus to the bloodstream via the regional lymph nodes.

#### 2.6.3.2 Non-vector transmission

The non-vector transmission of ZIKV can occur through mother-to-child, sexually, blood transfusion or direct transmission and organ transplantation. The vertical transmission of ZIKV from an infected woman to her unborn fetus can occur during all trimesters of pregnancy resulting in microcephaly (smaller than normal head size) and other congenital malformations in the infant, collectively referred to as congenital Zika syndrome (WHO,

2018). The virus can also cross the placental barrier and infect fetal neuronal tissue and antigens in fetal brain tissue as well as in the amniotic fluid. Sexual transmission of ZIKV has been reported in several cases involving travellers from endemic areas.

Like transmission of other flaviviruses (dengue, yellow fever and chikungunya), the transmission of ZIKV through blood transfusion may also be possible. Direct transmission of ZIKV is thought to occur through contact with the skin or mucous membranes of an infected host although; this is not a common route of transmission.

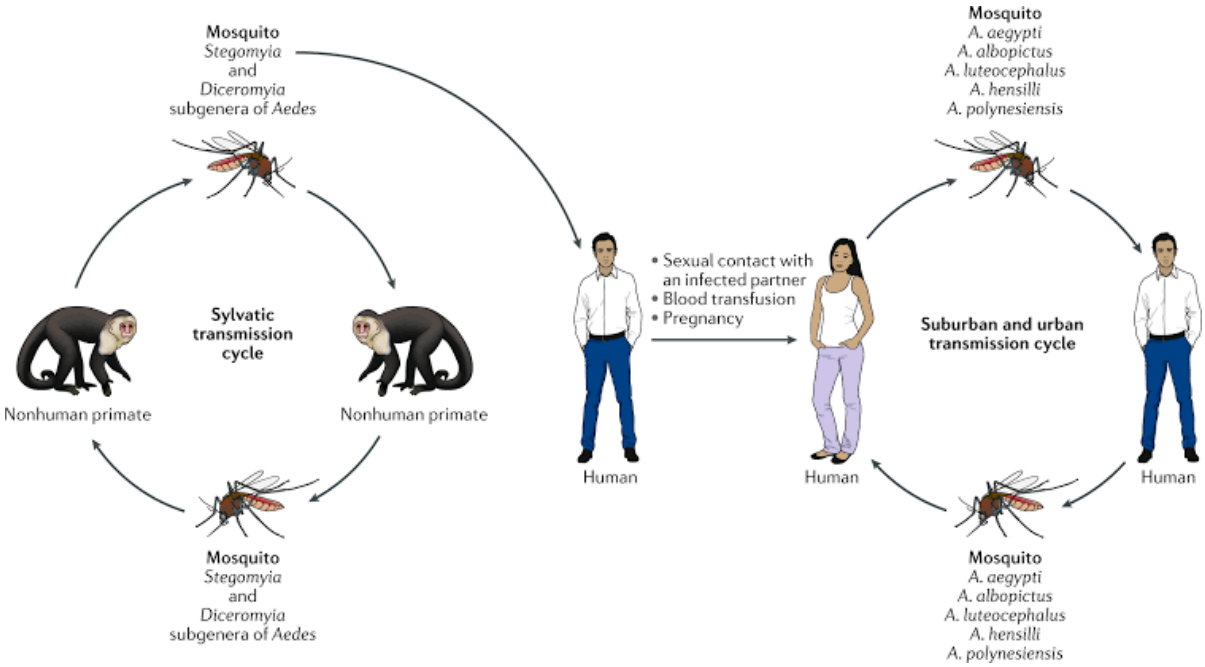



**Figure- 18: Transmission cycle of Zika (Kurscheidt et al., 2019)**

### 2.6.4 Epidemiology

Zika virus (ZIKV) has emerged as a public health problem around the world over the past few years. It was first detected in Uganda in Africa in 1947, from where it spread to Asia in the 1960s, it emerged in 2007 on Yap Island in Micronesia and hit most islands in the Pacific region in 2013. Subsequently, ZIKV was detected in the Caribbean, and Central and South America in 2015, and reached North America in 2016. Although ZIKV infections are in general asymptomatic or cause mild self-limiting illness, severe symptoms have been described including neurological disorders and microcephaly in newborns. The spread of Zika has been declared an emerging global health threat by WHO (2016) due to an alarming health situation. Since 2016, a sum of 20 countries in the Americas has reported ZIKV infections. Its link with the virus was first noted during the outbreak in Brazil in 2015, where

similarly, an increase in the incidence of microcephaly was observed in a temporal and geographic association with Zika virus infection (Chen et al., 2016).

### 2.6.5 Burden in India

India reported the first four cases of ZIKV infection in 2017; three were in Gujarat State (one which had occurred in late 2016), and one in Tamil Nadu. ZIKV outbreak was detected in the State of Rajasthan in 2018 (Figure- 19). National Centre for Disease Control, Ministry of Health and Family Welfare reported 159 confirmed cases of ZIKV infection from Rajasthan state (including 63 pregnant women), 130 cases from Madhya Pradesh, and 1 case from Gujarat state (NCDC, 2018; WHO, 2018).


**Figure- 19: Geographical distribution of Zika presence report in India from 2017 to 2021 (Yadav et al., 2022)**

A survey by the National Institute of Virology (NIV), Pune in 1954 showed that ZIKV antibody was present in 16.8 per cent of the samples tested from Bharuch district (Gujarat). An investigation of viral sequence analysis of five specimens from an outbreak in Rajasthan

identified circulation of the Asia lineage-Asian strain, demonstrating the outbreak potential of the older Asian strain.

During the period January to September 2021, two outbreaks of Zika Virus Disease were reported from Kerala (July 2021) and Maharashtra (July 2021). About 64 cases of Zika Virus Disease were reported from Thiruvananthapuram, Ernakulam and Kottayam districts in Kerala. One case of Zika virus disease was reported from Pune district of Maharashtra (DH & MoHFW Annual report, 2021-22).

Recent study (Yadav et al., 2022) indicates that the spread of ZIKV to newer areas where it had never been reported earlier, thus establishing local transmission of ZIKV in India. Overall, from 2017 to 2021, the presence of ZIKV has now been reported in 16 states/UTs (Assam, Bihar, Delhi, Gujarat, Himachal Pradesh, Jharkhand, Madhya Pradesh, Kerala, Punjab, Maharashtra, Uttar Pradesh, Rajasthan, Tamil Nadu, Telangana, West Bengal, Orissa and Uttarakhand) of India.

### 2.6.6 Global burden

Outbreaks have occurred sporadically in Africa, the Americas, Asia, and the Pacific. Until 2007, worldwide only 14 cases had been documented in humans. The first large outbreak was reported on the island of Yap (Federated States of Micronesia) in 2007. The first reports of locally transmitted infection came from Brazil in May 2015, although data is available to suggest that the virus originated in the Americas (Brazil) between October 2012 and May 2013. Eighty-six countries, territories, and sub-national areas have reported evidence of mosquito-borne ZIKAV transmission.

Phylogenetically three lineages' analyses have revealed: two African lineages, i.e., the MR 766 cluster and the Nigerian cluster, and one Asian lineage. The Asian lineage was first identified in Asia and subsequently spread to the Pacific Islands and then to the Americas. During 2015–16 epidemic that occurred in America was due to the strain of the Asian lineage generally known as the American strain. The strain of the Asian lineage that had been and continues to circulate in Asia was referred to as the "Asia lineage-Asian strain" or the "older" Asian strain (WHO, 2019). Nearly 87 countries and territories had an occurrence of native Zika virus (ZIKV) up to July 2019 and distributed across four of the six WHO Regions namely African Region, Region of the Americas, South-East Asia Region, and the Western Pacific Region). In America, the incidence of ZIKV infection was highest in 2016 and then considerably reduced in 2017 and 2018.

# 2.7 LEISHMANIASIS

## 2.7.1 Introduction

Visceral leishmaniasis or kala-azar is a widespread tropical disease caused by a protozoan parasite, which is spread by the bite of phlebotomine sandfly *Phlebotomus argentipes*. 90 sandfly species are known to transmit *Leishmania* parasites. The disease is endemic in large areas of the tropics, sub-tropics and the Mediterranean basin. In India, the disease is so far known to be anthroponotic. Asymptomatic cases are known to exist in endemic areas and may act as an important reservoir for transmission (Hasker et al., 2013). Outside India, the disease is reported to be zoonotic involving extra human reservoirs and various other species of sandfly. In humans, leishmaniasis has three general forms – cutaneous, mucocutaneous and visceral and different species of *Leishmania* tend to cause each type.

### Cutaneous leishmaniasis

Cutaneous leishmaniasis produces skin lesions mainly on the face, arms and legs. Although this form is often self-healing, it can create serious disability and permanent scars. Cutaneous leishmaniasis known as oriental sore, tropical sore, chiclero ulcer, or chiclero's ulcer is the most common form of leishmaniasis affecting humans. It is a skin infection caused by a single-celled parasite. The disease is transmitted by the bite of a phlebotomine sandfly. There are about twenty species of *Leishmania* that may cause cutaneous leishmaniasis.

### Mucocutaneous leishmaniasis

Mucocutaneous leishmaniasis, also called 'espundia' in South America, causes disfiguring lesions to the face; it destroys the mucous membranes of the nose, mouth and throat.

### Visceral leishmaniasis

Visceral leishmaniasis, also known as 'kala-azar', is characterized by irregular fever, and weight loss and affects several internal organs (usually spleen, liver, and bone marrow. The incubation period can be months or years and, unlike the cutaneous forms of leishmaniasis, it involves the internal organs. Two organisms *i.e., L. donovani* and *L. infantum* cause the majority of visceral leishmaniasis cases (most serious form). Visceral leishmaniasis is characterized by damage to the internal organs, and fully symptomatic cases are considered life-threatening.

### 2.7.2 Causative agent and vector

Leishmaniasis is caused by obligate intracellular protozoa of the Genus *Leishmania*. Human infection is caused by about 21 out of 30 known species. These include the *L. donovani* complex with three species - *L. donovani*, *L. infantum* and *L. chagasi*. In India, *Leishmania donovani* is the only parasite that causes the disease.

Human visceral leishmaniasis is mainly caused by *Leishmania donovani* and *L. infantum*. At one time, two different names were used for the latter organism - *L. infantum* in the "Old World" (Eastern Hemisphere) and *L. chagasi* in the "New World" (Western Hemisphere). Two morphologically distinct stages in the life cycle of the parasite are as below:

- Amastigote (aflagellate) or *Leishmania* stage: occurs in man (Figure- 20)
- Promastigote (flagellate) or Leptomonad stage: occurs in gut of sandfly and artificial culture.

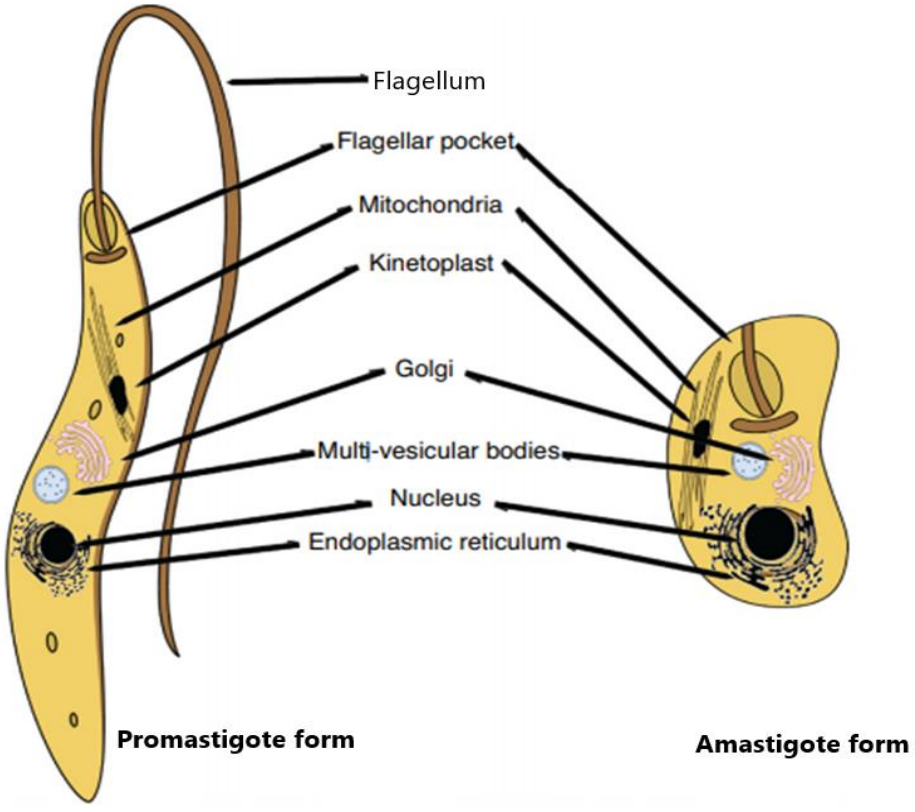



**Figure- 20: Parasite *Leishmania donovani* (Zulfiqar et al., 2017)**

Among the 35 known species of the sandfly, *Phlebotomus argentipes* is the only vector of Kala-azar in India. Sandflies are small insects and the length of a sandfly body ranges from 1.5 to 3.5 mm (http://nvbdcp.gov.in).

### 2.7.3 Transmission

*Leishmania* is the obligate intracellular parasite existing in two morphologic forms, promastigotes and amastigotes. The *Leishmania* promastigotes are transmitted by sandfly to vertebrate hosts e.g., Canines, marsupials, edentates (anteaters, sloths, armadillos) and rodents. Once entering the bloodstream of reservoirs, promastigotes are phagocytosed (engulf) by the mononuclear phagocytic cells and are transformed into amastigotes that multiply through binary fission. On lysis of the host cell, the free parasites spread to new cells and tissues of different organs including the spleen, liver and bone marrow.

Amastigotes in the blood as well as in the monocytes are ingested during a blood meal by a female sandfly. Once ingested, the amastigotes migrate to the midgut of the sandfly and transform into the promastigotes. After a period of four to five days, promastigotes move to the esophagus reach to pharynx of the sandfly (Figure- 21).

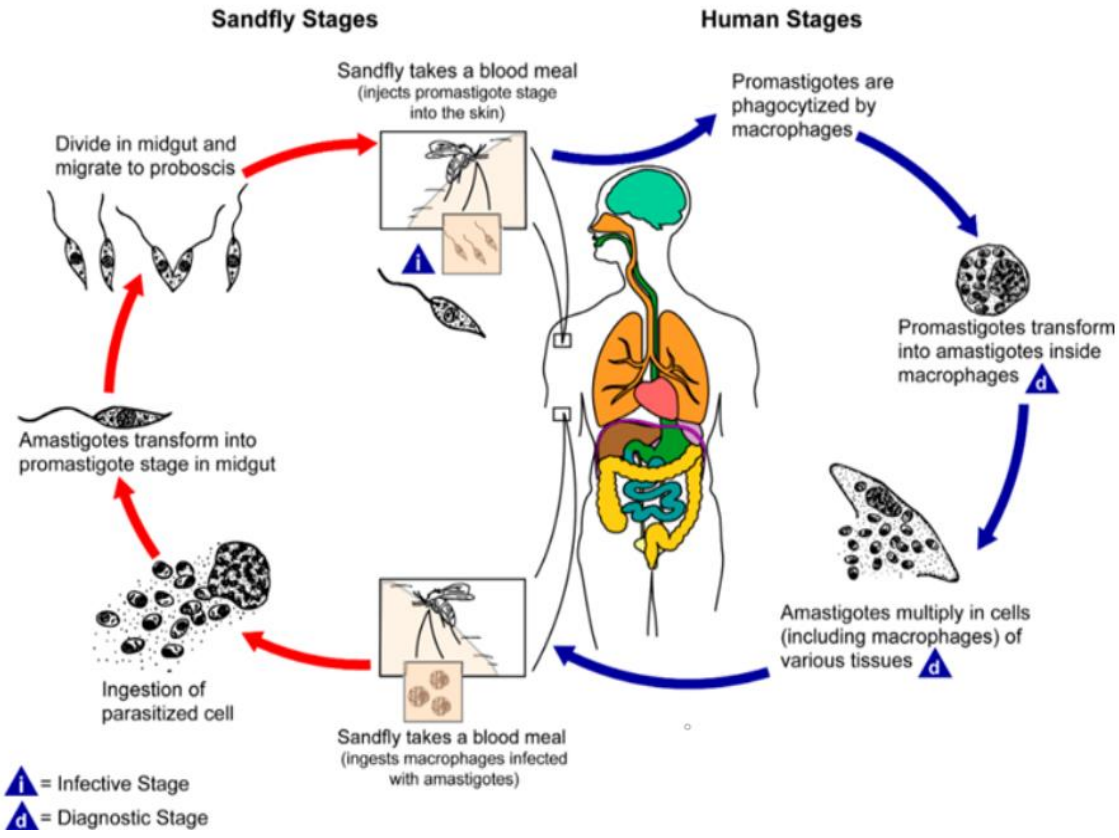



**Figure- 21: Transmission cycle of Leishmaniasis (Hailu et al., 2005)**

### 2.7.4 Epidemiology

Leishmaniasis is a disease with a wide distribution and reported in about 89 countries (Reithinger et al., 2007). The ecologic settings range from rain forests to deserts.

Leishmaniasis is usually more common in rural areas than in urban. It is reported in the outskirts of some cities. Climate and other environmental changes have the potential to expand the geographic range of the sandfly vectors and the areas in the world where leishmaniasis is found (https://www.cdc.gov/parasites/leishmaniasis/epi). It prevails throughout different geographical regions of the globe but occurs more specifically in the tropics and sub-tropics of Africa, South and Central America, the Middle East, Southern Europe and Asia. In 2012, the WHO led an effort to report on the burden and distribution of leishmaniasis in 102 countries, areas, or territories worldwide to identify cases of Cutaneous leishmaniasis (CL) and Visceral leishmaniasis (VL) and the data until 2010 indicate that 90% of global cases of VL occurred in Bangladesh, Brazil, Ethiopia, India, South Sudan and Sudan. About 70% of CL cases occurred in Afghanistan, Algeria, Brazil, Colombia, Costa Rica, Ethiopia, Iran, Sudan, and the Syrian Arab Republic (Torres-Guerrero et al., 2017).

It recurs in endemic cycles of about 10 years with an inter-epidemic period of 15 to 20 years. Up to 30% of *P. argentipes* become infected when fed on nodules and depigmented patches of Post Kala-azar Dermal Leishmaniasis (PKDL). The onset of PKDL also increases considerably. The peak onset of the disease occurs during the winter and spring months. Monsoon period is the transmission season of the disease.

### 2.7.5 Burden in India

Epidemic in 1970 was mainly restricted to Bihar and a few districts of West Bengal and also in neighbouring countries like Nepal and Bangladesh. The detection of Kala-azar in eastern Uttar Pradesh indicates the westward movement of the disease. Kala-azar is presently endemic in 54 districts in the country of which 33 districts are from Bihar, 4 districts from Jharkhand, and 11 districts from West Bengal, besides that cases occurred in 6 districts of eastern Uttar Pradesh. On the other hand, sporadic cases are also reported from other geographic areas of India viz., Assam, Gujarat, Himachal Pradesh, Jammu and Kashmir, Kerala, Madhya Pradesh, Sikkim, Uttarakhand and Tamil Nadu. The state of Bihar alone contributes >70% of the total Kala-azar reported from the four states. There has been a significant decline from 80,000 cases in 1992 to less than 9,000 in 2015. Since 2011 the cases have declined by 74%. Mortality also reduced from 90 deaths in 2011 to 5 deaths in 2015 (Figure- 23) and PKDL cases were reduced from 1982 cases in 2017 to 412 in 2020 (Figure-24).

In Bihar, 33 out of 38 districts are affected of which 10 districts have 200 or more cases annually and contribute to about 73% of the country's total. In approximately 12000 villages, about 99 million of the population is at risk. In Jharkhand, out of 24 districts four viz. Godda, Sahibganj, Dumka and Pakur are endemic to kala-azar and about 5.7 million people from approximately 1336 villages are at risk. West Bengal has 11 affected districts out of 20 districts with 28.18 million people at risk from 731 villages. In Uttar Pradesh, kala-azar cases have been reported in 9 districts out of 75 districts and 4.82 million population is at risk (NVBDCP, 2017).

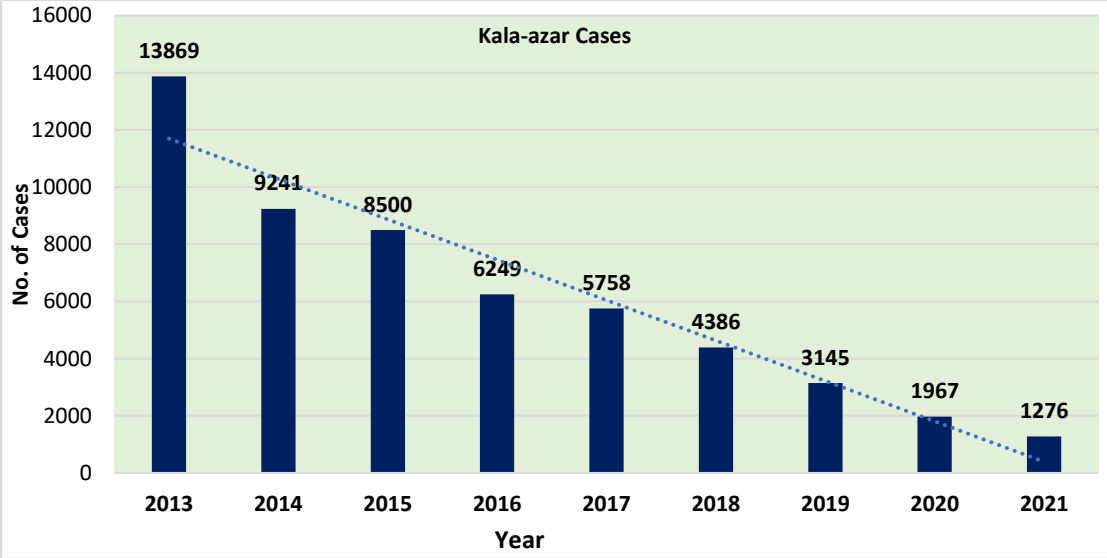



**Figure- 22: Kala-azar cases in India during 2013-2021**

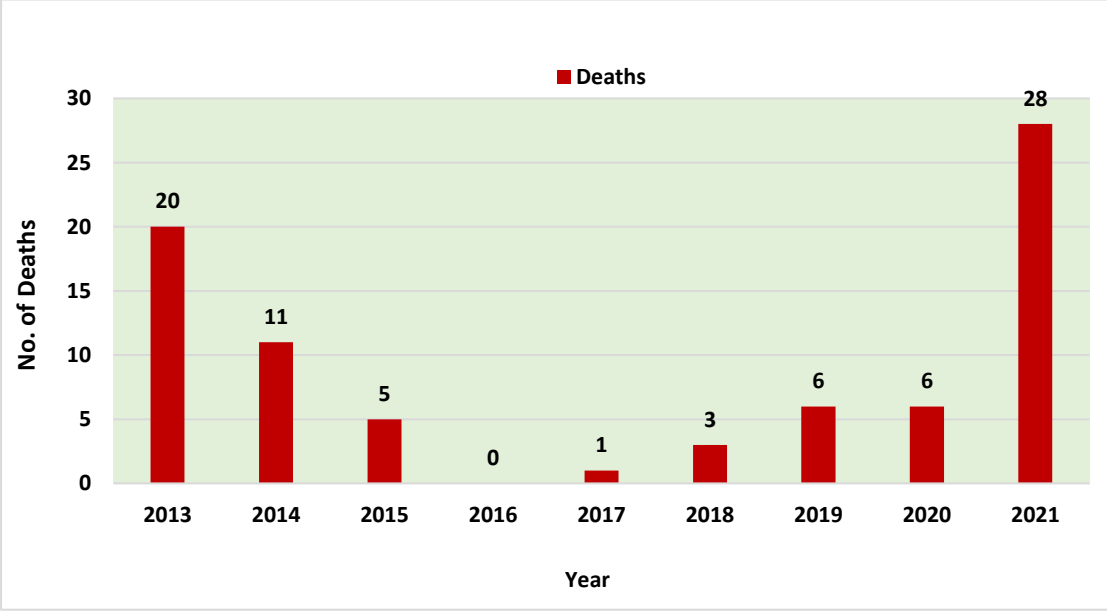



**Figure- 23: Kala-azar deaths during 2013-2021 in India**

Kala-azar cases have been declined gradually from 2013 to 2021, which is depicted in Figure- 23 and deaths also declined from 2013 to 2015, during 2016 death were not recorded and from 2017 to 2020 deaths increased as gradually 1, 3, 6, 6 and abruptly 28 during 2021 (Figure- 22) (htpp://nvbdcp.gov.in).

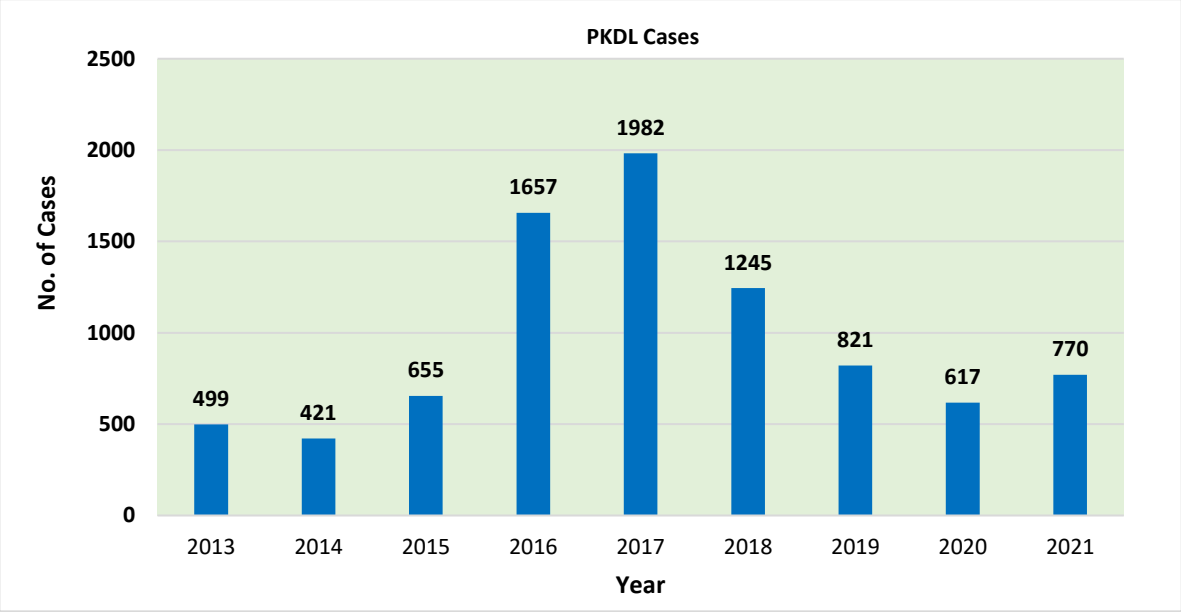



**Figure- 24: PKDL cases during 2013-2021 in India (NCVBDC)**

### 2.7.6 Global burden

In African regions visceral, cutaneous and mucocutaneous leishmaniasis are endemic in Algeria and countries in East Africa, which are highly endemic. In the region of the Americas, the epidemiology of cutaneous leishmaniasis in Americas is very complex, with variations in transmission cycles, reservoir hosts, sandfly vectors. In eastern Mediterranean region accounts for 70% of the cutaneous leishmaniasis cases worldwide. In India, cases of CL were reported from Rajasthan, Himachal Pradesh and J&K. In Mediterranean, Eastern Africa and Latin American regions cutaneous and visceral leishmaniasis are endemic.

In South-East Asia region, visceral leishmaniasis is the main form of the disease in this Region, is also endemic cutaneous leishmaniasis. The region is the only one with an initiative to eliminate visceral leishmaniasis as a public health problem by 2020. In 2020, the Region observed some 2295 cases, is the lowest number on record. The Region is poised to achieve this target, with countries aiming to have WHO validate elimination by 2023 (WHO, 2022). Most cases occur in Brazil, East Africa and India. An estimated 50 000 to 90 000 new cases occur worldwide annually, with only 25% to 45% reported to WHO.

# 2.8 PLAGUE

## 2.8.1 Introduction

Plague is primarily a disease of rodents and their fleas, which can also infect humans. It is transmitted between rodents by their ectoparasitic fleas and can be transmitted to people when infected rodent fleas bite them. It is a disease of great antiquity and the first plague pandemic was in 542 B.C. and lasted almost 60 years. The second and most severe pandemic was in the 14$^{th}$ century, also known as the Black Death causing an estimated 50 million deaths, approximately half of them from Asia and Africa and the rest from Europe (where a quarter of the population succumbed). The final and most recent pandemic occurred in 1894 and started in Yunan Province in China and spread to many countries through maritime trade. Plague is an important zoonotic disease and exceptionally virulent flea-borne illness caused by the gram-negative bacterium *Yersinia pestis*. Plague is the cause of significant mortality in susceptible rodents and rabbits. In some animals such as prairie dogs, outbreaks may kill nearly all of the animals in a colony. In India the reservoir for the disease is the wild rodents viz., Indian gerbil (*Tatera indica*) and the Lesser Bandicoot (*Bandicoota bengaliensis*), whereas the domestic rodents viz. *Rattus rattus, Bandicoota indica* and *Mus musculus* are susceptible to the infection.

## 2.8.2 Causative agent and vector

Genus *Yersinia*, a member of the Family Enterobacteriaceae, consists of 11 species, of which three are human pathogens- *Y. pestis, Y. pseudotuberculosis* and *Y. enterocolitica*. The species *Y. pestis* is a gram-negative, nonmotile, non-spore-forming coccobacillus with a size of 0.5 to 0.8 mm in diameter and 1 to 3 mm long. It has a typical cell wall, whole-cell lipid compositions and an enterobacterial antigen, in common with other enteric bacteria.

Among the Enterobacteriaceae, *Y. pestis* is unique in both its choice of host habitat (blood, lymphoid system, reticulo-endothelial system) and primary mode of transmission (flea vectors). It has two main habitats in the stomach of the proventriculus of various flea species at ambient temperature or in the blood or tissues of a rodent host at body temperature. Fleas are the natural vectors of plague in the world. The principal vector of plague in India is *Xenopsylla cheopis* (Figure- 25) because of its close association with man and worldwide distribution. Apart from *X. cheopis, X. brasiliensis* and *X. astia* can also act as a vector.

### 2.8.2.1 Types of plague and their symptoms

There are three main forms of plague in humans viz., bubonic, septicemic and pneumonic. Bubonic plague primarily affects the lymph nodes. Septicemic plague affects the bloodstream and can be contracted by handling infected animals. Pneumonic plague affects the lungs and can spread from person to person, though rarely, through contaminated air droplets. Most instances of the disease in humans are of the bubonic form, which emerges by a bite from an infective flea, which has previously fed on an infected rodent. Bubonic plague is the most common form of illness. Signs include fever, chills, and very swollen, painful lymph nodes, called "buboes". It is the most common form, which is less fulminant, but also has a high mortality rate if left untreated. Septicemic plague occurs when bacteria spread throughout the body. Pneumonic plague, which is a particularly deadly form of the disease is usually fatal if antibiotics are not started very soon after the symptoms appear. Pneumonic plague is less common but the deadliest form. It occurs when the bacteria are inhaled and infect the lungs. This form can be spread to other people by coughing.

Out of two kinds of plague, wild plague exists in its natural foci independent of human populations and their activity. Domestic plague is intimately associated with rodents living with humans and can produce epidemics in both and animal-human populations. Plague is now largely focal in distribution. It spreads rapidly in conditions of war and other catastrophes, e.g. earthquakes. Epidemics still occur from time to time after a prolonged quiescence in the erstwhile endemic areas.

**Figure- 25: *Xenopsylla cheopis* (Durden and Henkle, 2019)**

### 2.8.3 Transmission

The plague bacteria can be transmitted to humans in the following ways:

**Flea bites**: Plague bacteria are most often transmitted by the bite of an infected flea. During plague epizootics, many rodents die, causing hungry fleas to seek other sources of blood. People and animals that visit places where rodents have recently died from plague are at risk of being infected from flea bites. Dogs and cats may also bring plague-infected fleas into the home. Flea bite exposure may result in primary bubonic plague or septicemic plague (Figure-26).

**Contact with contaminated fluid or tissue**: Humans can become infected when handling the tissue or body fluids of a plague-infected animal. For example, a hunter skinning a rabbit or other infected animal without using proper precautions could become infected with plague bacteria. This form of exposure most commonly results in bubonic plague or septicemic plague.

**Infectious droplets**: When a person has plague pneumonia, they may cough droplets containing the plague bacteria into air. If these bacteria-containing droplets are breathed in by another person they can cause pneumonic plague.

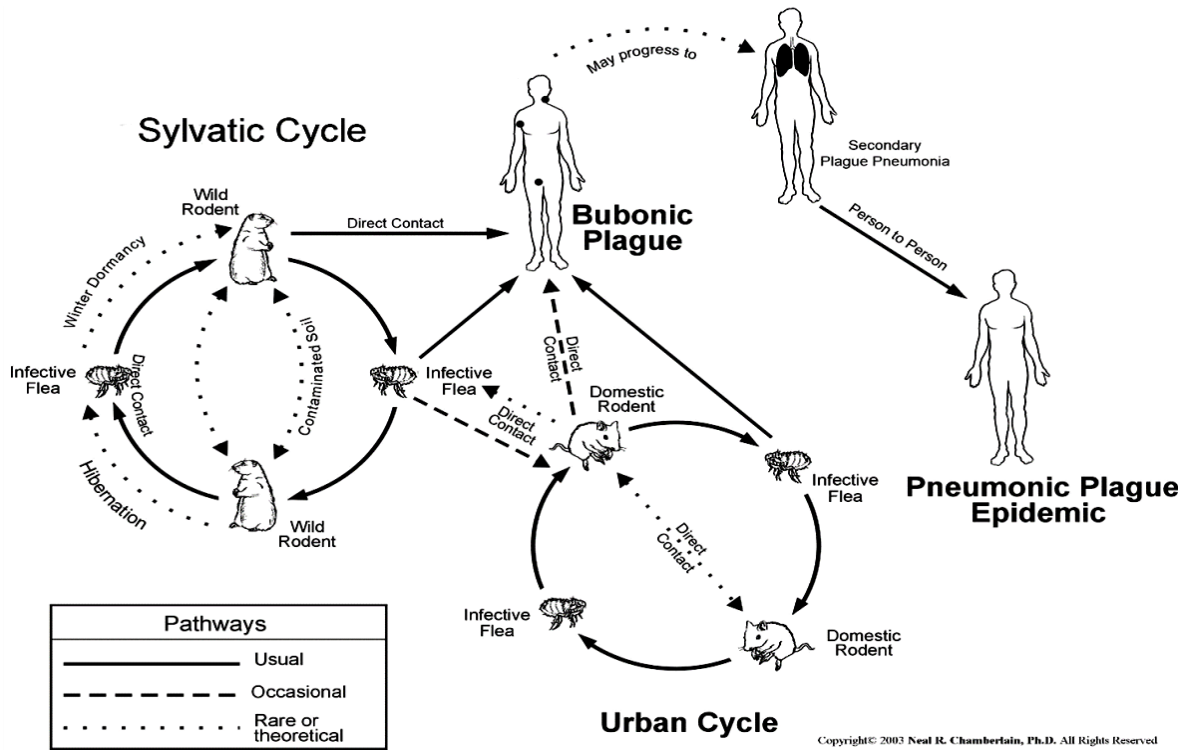



**Figure- 26: Transmission cycle of plague (Hunduma, 2016)**

### 2.8.4 Epidemiology

In the wild, *Y. pestis* seems to be maintained in cycles between wild rodents or lagomorphs and fleas. Periodically, these animals experience epizootics, increasing the risk of transmission to other species. Whether *Y. pestis* circulates in its epizootic hosts between outbreaks, or a different 'maintenance' host, is controversial.

Plague has become widespread in the last two millennia, and affects a large number of countries on most continents during several pandemics. The first certain pandemic, known as Justinian plague, was recorded in the sixth century AD. Between 542 and 546 AD epidemics in Asia, Africa and Europe claimed nearly 100 million deaths. The second plague pandemic was during the fourteenth century (1347-1350). This pandemic was the beginning of a number of outbreaks of plague, which ravaged Europe and Africa in subsequent centuries (WHO, 2000).

### 2.8.5 Burden in India

Plague, a disease of great antiquity was a major public health problem throughout India till the mid 20$^{th}$ century AD. The authenticated plague epidemic started in the year 1895-1908 and reached its peak in 1907. During the two decades from 1898-1918, there were over 25 million deaths (Figure- 27) in India (including Pakistan and Bangladesh). The decennial death rates of plague in India per 1,00,000 population during these decades were 183.3 and 133.8 respectively (Table- 9). Since then, mortality due to plague had declined to reach zero level in 1967 and the last confirmed human case of plague in India was reported from Mulbagal, Kolar District, Karnataka in 1966.

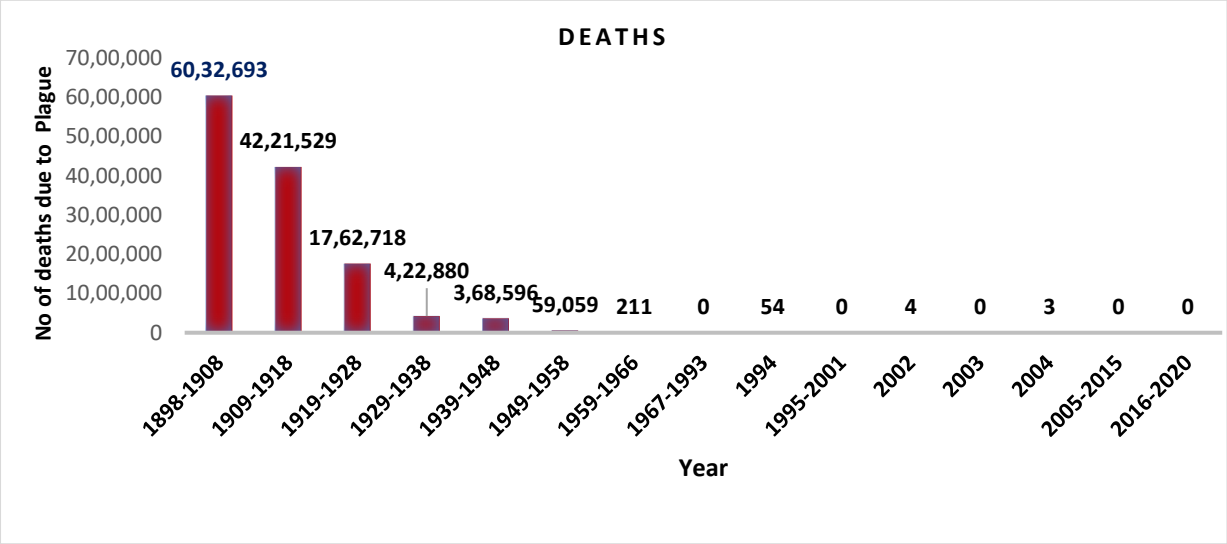



**Figure- 27: Plague deaths during 1898-2020 in India (Biswas, 2018)**

**Table- 9: Decennial mortality trend of plague in India (Biswas, 2018)**

| Period | Number of total deaths due to plague |
|---|---|
| 1898-1908 | 6,032,693 |
| 1909-1918 | 4,221,529 |
| 1919-1928 | 1,762,718 |
| 1929-1938 | 4,22,880 |
| 1939-1948 | 3,68,596 |
| 1949-1958 | 59,059 |
| 1959-1966 | 211 |
| 1967-1993 | Nil |
| 1994 | 54 |
| 1995-2001 | Nil |
| 2002 | 4 |
| 2003 | Nil |
| 2004 | 3 |
| 2005-2021 | Nil |

Though human plague had not been reported from India since 1966, sporadic cases of suspected human plague had been reported from Himachal Pradesh (Mahasu village in 1971 and Rohru tehsil in 1983 of Shimala district), Karnataka (Attibele, Bangalore rural district in 1984) and at times localized sylvatic plague incidence encountered in the last decade from South Indian tri-junction of Andhra Pradesh, Tamil Nadu and Karnataka. Re-emergence of plague in India, after a gap of 28 years in 1994 (876 cases, 54 deaths) in Surat, Gujarat (pneumonic plague) and in Beed, Maharashtra (bubonic plague) resulted in huge economic loss due to the panic associated with the disease. Later again in 2002, in Rohru, Himachal Pradesh and during 2004 in Barkot, Uttarakhand plague incidence has been recorded. The enzootic and sylvatic plague foci in India (Figure- 28) are present in four groups of foci in northern, central, western and southern India.

### 2.8.6.1 Plague surveillance activities

Persistence of plague disease pathogens in reservoirs and reappearance after long periods of quiescence need continuous surveillance. High index of clinical suspicion of symptomatic cases, rapid laboratory diagnosis by carrying out confirmatory and prompt treatment with antibiotics. Routine Plague Surveillance measures are being undertaken in erstwhile endemic areas (10 districts located in seven endemic states) of the country. The plague control units functioning under the respective state health department routinely carry out trapping/collection of rodents, collection of sera and rodent organs, transportation to the respective labs, and rodent ectoparasite survey. They also carry out rodent and flea control as and when required. These activities are being coordinated by Plague surveillance unit of NCDC, Bangalore. The central Plague laboratory situated in the Zoonosis division of National Centre for Disease Control (NCDC) Delhi monitors the entire field and laboratory plague surveillance activities, in the country as a nodal organization.


**Figure- 28: Enzootic foci of plague in India (Biswas, 2018)**

In the plague laboratory the specimen is collected from rodents' blood, organs, carnivore animals (dog) sera, Humans blood and fleas from endemic/ suspected outbreak areas, These

specimens are routinely subjected to bacteriological work by detection, isolation and identification of *Y. pestis* and molecular characterization of strains The serological activities by_detection of antibodies against F-1 antigen of *Y. pestis*. The laboratory entomological works by identification of flea calculation of specific flea index, insecticide susceptibility testing and identification of Rodents.

As per the International Health Regulation (IHR-2005) all the international air ports and Sea ports in the country have to be kept free from rodents to prevent migration vis-à-vis transmission of rodent borne diseases particularly Plague from endemic zones to disease free zones.

### 2.8.6 Global burden

World Health Organization figures indicate that there is still a public health problem from the plague, especially in Africa, Asia and South America. Although the incidence trend was downwards until 1981, there has been an apparent increase in the incidence of disease over the last decade, possibly because of more efficient diagnosis and reporting of cases. According to the notification received by WHO during the period from 1954 to 1997, plague affected 38 countries with 80,613 cases and 6,587 deaths. During 1989-2003, twenty-two countries from Africa, America and Asia reported 35,429 cases and 2,749 deaths respectively during the period. Among the Asian countries China, India, Indonesia, Kazakhstan, Mongolia, Myanmar and Vietnam have reported plague cases and deaths. Globally, human plague outbreaks are regularly reported to WHO, for example, from India in 2004, Indonesia in 2007, the Democratic Republic of the Congo and the United Republic of Tanzania in 2014, and the outbreak of pneumonic plague reported in Madagascar in 2017 (WHO, 2021).

Plague continues to be a threat because of vast areas of persistent wild rodent infection, contact of wild rodent plague exists in the western half of the USA large areas of South America North Central Eastern and Southern America North Central Eastern and Southern Africa central eastern and Southern Asia and extreme Southern Europe near the Caspian Sea.

## 2.9 SCRUB TYPHUS

### 2.9.1 Introduction

Scrub typhus is a mite-borne disease caused by *Orientia tsutsugamushi* (formerly *Rickettsia*), first described in 1899 in Japan and transmitted to humans by infected chigger mites (larval stage of Trombiculidae mites). This is found only in areas with a suitable climate, plenty of moisture and scrub vegetation. Scrub typhus affects humans of all age groups. Humans are accidental hosts of this zoonotic disease. It is confined geographically to the Asia Pacific region. A billion people are at risk and nearly a million cases are reported every year. In India, scrub typhus broke out in an epidemic form in Assam and West Bengal during the Second World War. *O. tsutsugamushi* is transmitted through the biting of the larva of infected *Leptotrombidium* mites. The term "scrub" is used because of the type of vegetation (terrain between woods and clearings) that harbours the vector. The word "typhus" is derived from the Greek word 'typhus' means 'fever with stupor or smoke', 'Tsutsuga' means 'small and dangerous' and 'Mushi' means 'insect or mite'. Historically, scrub typhus had been endemic in Asia, Australia and islands in the Indian and Pacific Oceans, known as the "tsutsugamushi triangle".

### 2.9.2 Causative agent and vector

The causative agent of scrub typhus is *Orientia tsutsugamushi*, a bacterial pathogen, which is small in size (0.3 to 0.5 by 0.8 to 1.5 µm), a gram-negative, obligate intracellular bacterium of the family *Rickettsiaceae.* Mite *Leptotrombidium deliense* is the vector of scrub typhus and belongs to the subfamily Trombiculinae of the tribe Trombiculini. In addition to this mite species, *Schoengastiella ligula* of the tribe Gahrliepiini has also been incriminated as a vector in India (Tilak et al., 2011).

### 2.9.3 Transmission

Scrub typhus is transmitted by the bite of a mite *L. deliense.* The infection is transmitted to man and rodents by some species of infective Trombiculid mites ("chiggers", *L. deliense* and others), which feeds on lymph and tissue fluid rather than blood. *O. tsutsugamushi* is maintained in trombiculid mites through transstadial and transovarial transmission. Transstadial transmission occurs when a pathogen is preserved through the larval stage (protonymph and into the deutonymph stages), which means the infection passes from the egg to the larva or adult. This can, with some pathogens and parasites, result in horizontal

transmission when one stage (*i.e.*, larva) acquires the infectious agent and a later stage (*i.e.*, deutonymph) infects a naive host (Figure- 29). Transovarial transmission (also known as vertical transmission) is the process by which the female passes the pathogen to the eggs.

Human beings are infected when they walk into 'mite islands' (areas in the soil where the micro ecosystem is favourable for mites) and are bitten by the mite larvae known as chiggers. The mite feeds on the serum of warm-blooded animals only once during its cycle of development, and adult mites do not feed on man. The microbes are transmitted through ovarian transmission. Chiggers are the only parasitic stage. They use hair follicles and pores to gain entry into the skin and feed for 3–5 days using a stylostome (feeding tube) to inject salivary secretions that dissolve host tissue. This dissolved tissue is ingested by larval mites.

As soon as *Leptotrombidium deliense* mites are infected in nature by feeding on the body fluids of mammals like rodents, they maintain infection throughout their life stages and as adults. The incubation period lasts for 1-3 weeks.

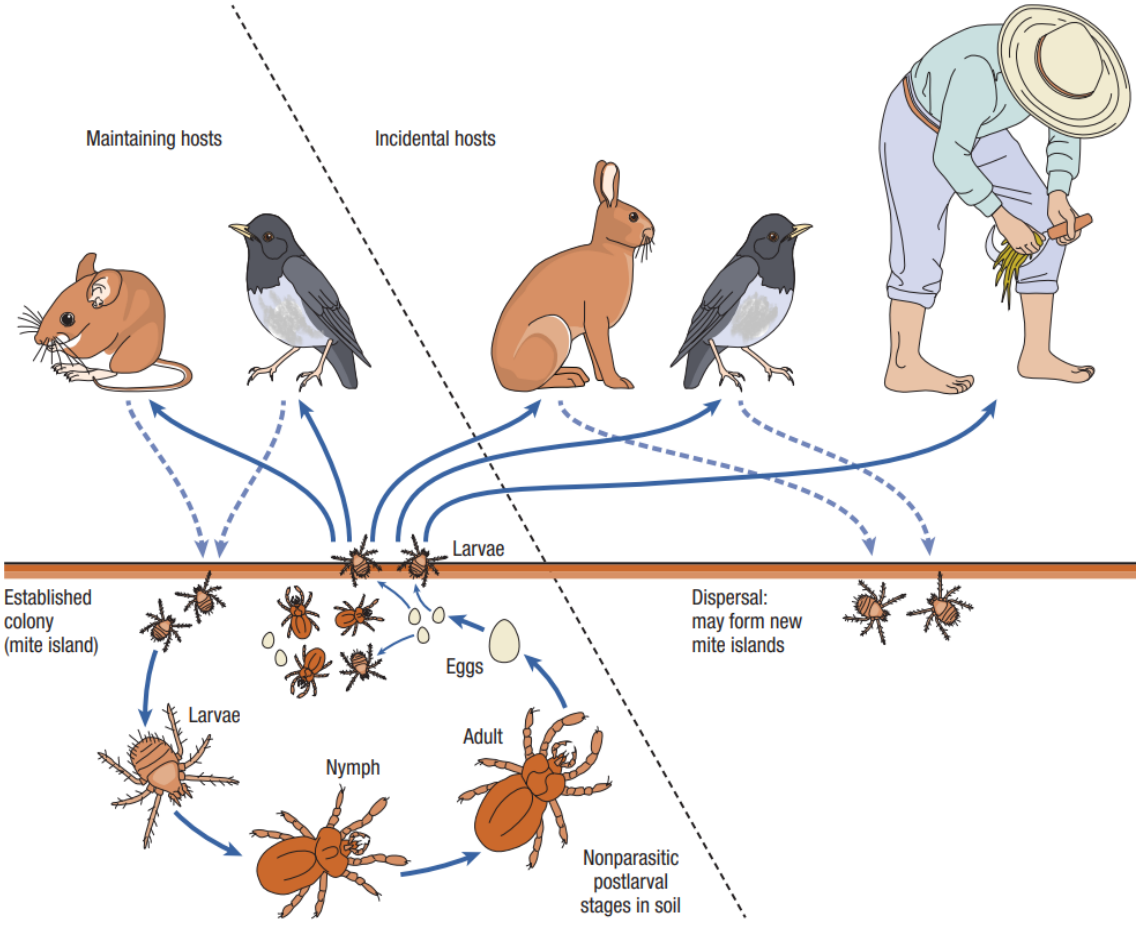



**Figure- 29: Transmission cycle of Scrub typhus (Wangrangsimakul et al., 2020)**

### 2.9.4 Epidemiology

One billion people are at risk of infection, and the endemic area of scrub typhus is highly populated. The progress of globalization and associated travel contributes to the exportation of infected persons to non-endemic areas. Mites don't prefer too moist or too dry areas as ground vegetation may be sparse to support mite populations. Thus, extreme precision is required for transmission to humans. While these transmission islands define a high degree of landscape specificity for the occurrence of scrub typhus, they are not necessarily rare across the landscape depending on where in the global "triangle" they are located. Thus, this unique transmission potential has resulted in widespread epidemics under conditions of human encroachment on natural habitats characterized by overgrown vegetation.

### 2.9.5 Burden in India

Periodic outbreaks of scrub typhus occurred in the early 1900s and scrub typhus was classified as a typhus-like fever in 1917 in India. It was a major cause of fever among military personnel along the Assam-India-Myanmar (formerly Burma) border during the Second World War and the 1965 Indo-Pak war. The disease resurged at the Pakistan border of India in 1990. In India, endemic foci are restricted to Andaman & Nicobar Islands, Bihar, Delhi, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Maharashtra, Manipur, Nagaland, Punjab, Rajasthan, Tamil Nadu and Uttarakhand (Figure- 31).

With wide distribution in many states of India, the disease occurs far and wide along hilly forest tract areas, semi-desert conditions and rural areas with a lot of bushes shrubs and long grasses around houses. Infection to humans is accidental and usually associated with the clearance of forest areas for developmental activities. The following environmental factors influence the scrub typhus outbreaks in an area viz. agricultural practices, urbanization, industrialization, and land reclamation and troop movement. In addition to this, the persons engaged in the occupations like honey collection, wood collection, fishing and hunting are prone to infection. The period of the epidemic is influenced by the activities of the infected mite. It occurs more frequently during the rainy season. The data in Figure- 30 depicts cases and deaths reported from India during 2010-2020. The peak season of disease occurrence was reported between August to November and mainly belongs to rural areas in India (Sinha et al., 2014; Varghese et al., 2006). Scrub typhus disease occurrence from South to Northeast and Northwest India is still underdiagnosed (Kala et al., 2020).

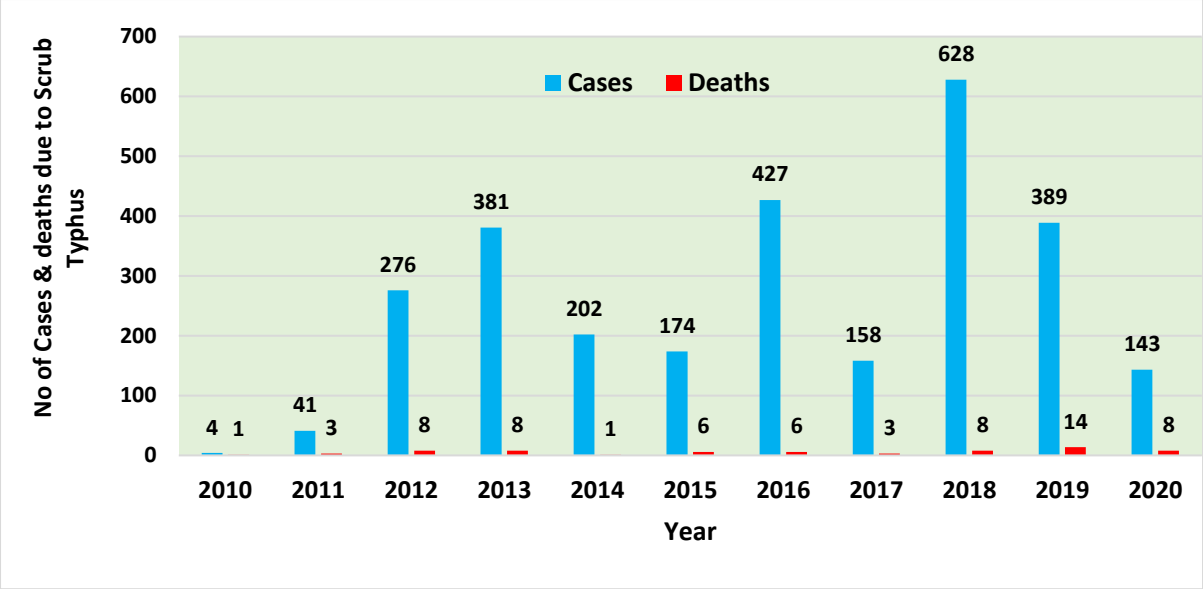



**Figure- 30: Scrub typhus cases and deaths reported from India during 2010-2020 (Panda et al., 2022)**

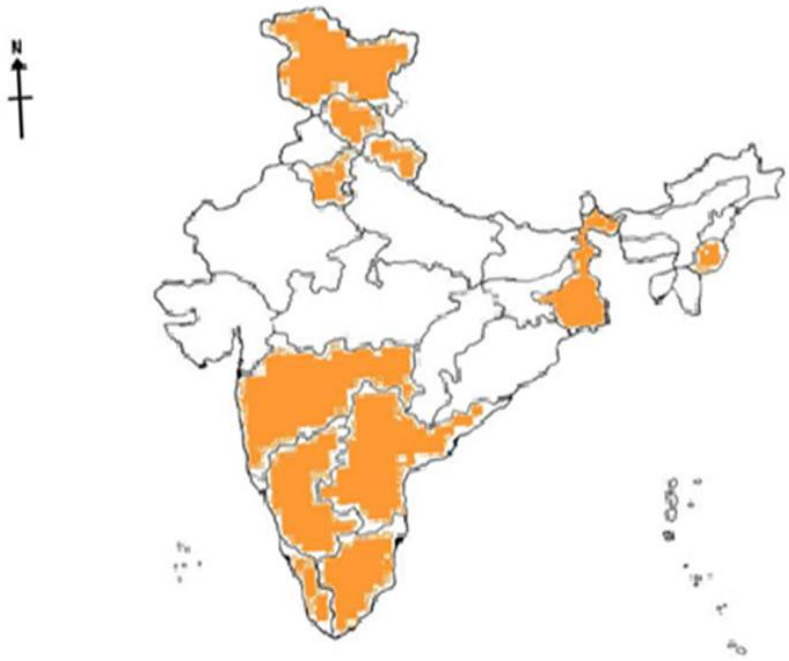



**Figure- 31: Scrub typhus endemicity in India (IDSP, NCDC)**

### 2.9.6 Global burden

Endemic area of scrub typhus is also known as the "tsutsugamushi triangle", (Figure- 32) which is distributed over a very wide area of 13 million $km^2$ bound by Japan in the east, through China, the Philippines, tropical Australia in the south, and west through India,

Pakistan, possibly to Tibet to Afghanistan, and southern parts of the USSR in the north. Scrub typhus is active in Japan, China, Philippines, Australia, India, Pakistan, Afghanistan, southern parts of the former USSR, Indonesia, Malaysia, Thailand and Vietnam. Geographic distribution of the disease occurs within an area of about 13 million square kilometer area. However, there are confirmed cases of increasing and spreading in other areas such as Dubai, United Arab Emirates, Chile, Peru, and Africa. The diversity of species and epidemic characteristics in other countries such as China, Japan, South Korea, Taiwan, Hong Kong, and Thailand (Panda et al., 2022). Recently, rickettsiosis re-emerged along the Thai Myanmar border. There are reports of the emergence of scrub typhus in Maldives Islands and Micronesia.

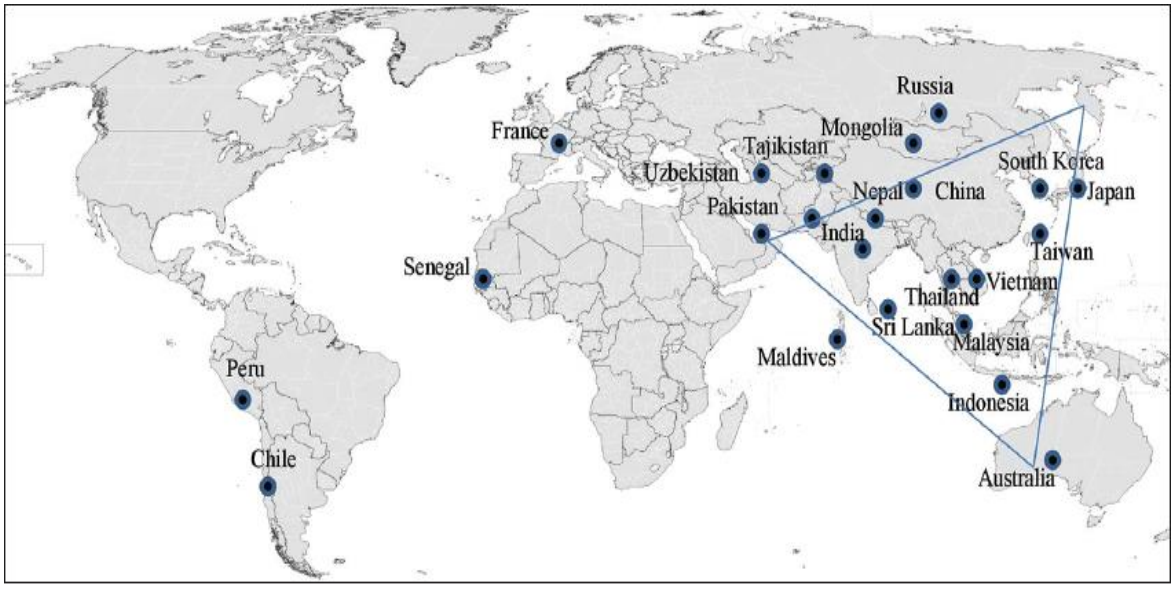



**Figure- 32: Geographical distribution of scrub typhus in "tsutsugamushi triangle (Xu et al., 2017)**

## 2.10 CRIMEAN-CONGO HAEMORRHAGIC FEVER (CCHF)

### 2.10.1 Introduction

Crimean-Congo Haemorrhagic Fever (CCHF) is a tick-borne viral disease, caused by Crimean-Congo Haemorrhagic Fever Virus (CCHFV), which belongs to the genus *Nairovirus* and the family Bunyaviridae. It is zoonotic (could be transmitted from animals to humans) VBD. The disease was first described in 1944 during World War II in a group of Soviet soldiers in the Crimean peninsula and was given the name Crimean hemorrhagic fever. In 1969 it was recognized that the pathogen causing Crimean hemorrhagic fever was the same as that responsible for an illness identified in 1956 in the Congo. The linkage of the two place names resulted in the current name for the disease and the virus. The disease has been reported in more than 50 countries in Africa, Asia, Eastern Europe and the Middle East.

The disease is characterized by fever and hemorrhage, often with nonspecific prodromal symptoms. CCHFV infection can be difficult to distinguish clinically from other causes of undifferentiated febrile illness and other viral hemorrhagic fevers (VHFs). It has a case fatality rate ranging from 5% to 80%. There is no specific treatment or vaccine against CCHF.

In India, the first laboratory-confirmed case was reported on 19$^{th}$ January 2011 from the Ahmedabad district of Gujarat. CCHF outbreaks constitute a threat to public health services because of their epidemic potential, high case fatality rate (10-50%), potential for nosocomial (hospital-acquired) infection and outbreaks and the difficulties in its treatment and prevention (WHO). The virus is carried asymptomatically in animals and poses a serious threat to human beings. Before 2011, serological evidence of CCHF in humans and livestock was reported by NIV Pune from Kerala, Pondicherry, Maharashtra and Jammu & Kashmir. The geographical distribution of CCHF coincides with that of *Hyalomma* ticks.

### 2.10.2 Causative agent and vector

The causative agent of CCHF is a Crimean-Congo haemorrhagic fever virus (CCHFV), which is spherical, enveloped, negative sense, single-stranded RNA virus with a tri-segmented genome. Ticks are arthropods, which suck blood from animals and humans. A number of tick genera are capable of becoming infected with CCHF virus, but the most efficient and common vector of CCHF is the member of *Hyalomma* genus under the family

Ixodidae. *H. anatolicum anatolicum* (Figure- 33) is the primary vector of CCHFV in India and the virus was isolated from tick species from Gujarat and Rajasthan.

**Figure- 33: Female and male of *Hyalomma anatolicum anatolicum* (Shastri et al., 1981)**

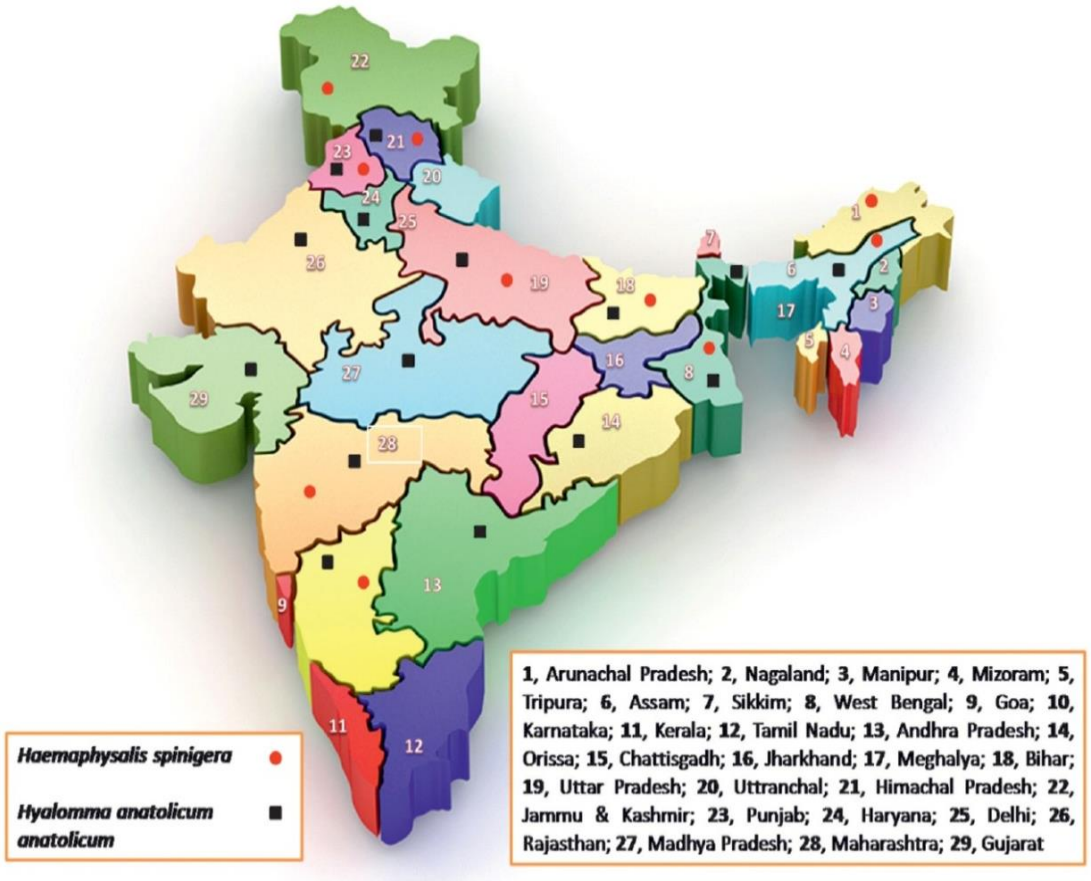



**Figure- 34: Distribution of *Haemaphysalis spinigera* (KFD vector) and *Hyalomma anatolicum anatolicum* (CCHF vector) in India**

These ticks are widely distributed in India (Figure- 34). The ticks are the natural reservoir of CCHF virus. Hyalomma spp. are medium to large-sized tough hardy ticks that survive where humidity is low and climatic conditions are extreme. They can be easily distinguished by four pairs of legs in adults and a lack of clear segmentation of the body. Both larvae and nymphs largely feed on lower vertebrates (such as rodents, rabbits, hares etc.), while the adults feed on higher vertebrates (such as cattle, goats, sheep, etc.). Male and female ticks suck blood and can act as a vector for disease transmission.

### 2.10.3 Transmission

The virus is maintained in nature predominantly in the Ixodid tick vectors, particularly ticks of the genus *Hyalomma*. CCHFV can persist in the tick vectors throughout its life stages by transstadial transmission and can be passed on to the offspring by transovarial transmission. Among domestic animals, cattle, sheep and goats play an important role in the natural cycle of the virus. In these animals, CCHFV replicates to high titres in the lung, liver, spleen and reticuloendothelial system in other organs, but generally causes only subclinical disease. In contrast, human infections often result in severe hemorrhagic fever with high levels of viral replication occurring in all major organs, including the liver. Human beings may also acquire the CCHF virus by direct contact with blood or other tissues of infected livestock or they may become infected through a tick bite or crushing of an infected tick. The epidemic of CCHF coincides with nymphal activity; hence nymphs are considered the most important stage for human transmission (Figure- 35).

Transmission is also possible if blood, body fluids and wastes from patients with the disease come into contact with broken skin or mucous membranes, as occurs when medical care personnel sustain accidental needle injury. In advanced stages of the disease, aerosol contact of the blood of the patient can also lead to transmission of the virus. CCHFV infection is most common in rural areas where exposure to ticks is higher and people get infected when bitten by infected ticks. Physical contact with infected body fluids or blood can transmit the virus from person to person within 7-10 days of illness (Aslam et al., 2016).

**Vertical transmission**

The virus is maintained by a cycle involving transovarial and transstadial transmission in *Hyalomma* spp. of ticks. Larval and nymphal ticks become infected when feeding on small mammals and ground-dwelling birds, and adult ticks when feeding on wild and domestic ruminants (sheep, goats and cattle). Infection in wild and domestic ruminants is

very productive, resulting in viremia levels high enough that ticks become infected, when feeding. Two types of vertical transmission are available in CCHF: transstadial and transovarial (Pierre, 2006).

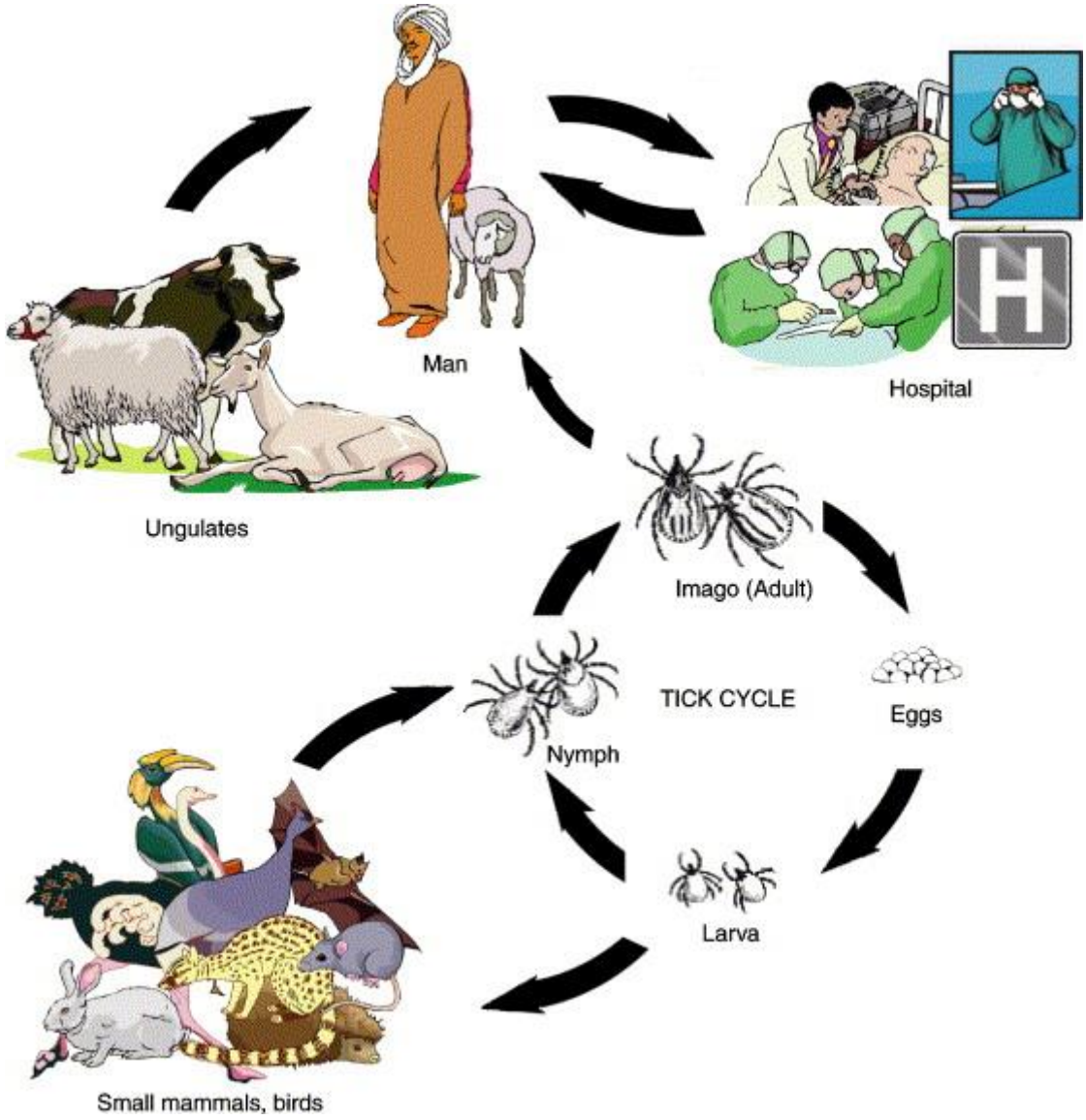



**Figure- 35: CCHF transmission cycle (Pierre, 2006)**

**Transstadial transmission** is the sequential passage of parasites/pathogens acquired during one life stage, or stadium, through the moult to the next stage(s) or stadium. For example, the virus acquired by larval ticks is passed transstadially to the nymphal stage and adult before they are transmitted to vertebrates.

**Transovarial transmission** is defined as the vertical passage of parasites/pathogens by an infected vector to its offspring through ovaries. While changing from larva to the adult stage

during metamorphosis, tick vectors support the replication of the virus present inside their body tissues. Following this, the virus is transmitted to eggs and to the next generation.

**Horizontal transmission**

The spread of CCHFV between ticks and animals is higher when larvae and nymphs develop into adult forms by taking the blood meal for their growth. A bite of the infected tick to their host *i.e*., small vertebrates, results in transmission of the virus.

### 2.10.4 Epidemiology

CCHF has the most widespread geographical distribution of all the tick-borne viruses that cause disease in humans, and the second widest geographical distribution of all arboviruses, after the dengue virus. Historical evidence points to the probable description of CCHF by a physician in Tajikistan in 1100 AD in a patient with hemorrhagic manifestations. The disease is endemic in many regions, such as Africa, Asia, Eastern Europe, and the Middle East. The known distribution of CCHFV covers the greatest geographic range of any tick-borne virus and there are reports of viral isolation or disease from countries across four regions: Africa (Democratic Republic of Congo, Mauritania, Nigeria, Senegal, South Africa, Sudan, Uganda), Asia (Afghanistan, China, India, Kazakhstan, Pakistan, Tajikistan, Uzbekistan), Europe (Bulgaria, Greece, Kosovo, Russia, Spain, Turkey), and the Middle East [Iran, Iraq, Kuwait, Oman, Saudi Arabia, United Arab Emirates (UAE)].

*Hyalomma* ticks favor dry climates and arid types of vegetation, areas with abundant small and large mammals that can support hematophagy and the different stages of the tick life-cycle. Environmental factors (such as climate) and human behavior are critical determinants for the establishment and maintenance of CCHF endemicity within an area. Anthropogenic activities may modify the risk of CCHFV transmission like changes in land use, recreational activities, movement and trade of infected livestock. There are 7 CCHFV genotypes: Asia-1, Asia-2, Euro-1, Euro-2, Africa-1, Africa-2, and Africa- 3, these are recognized by the region in which they originated and still circulate. More than one genotype can be found throughout multiple countries (Alam et al., 2013).

Most tick species are not restricted in range by their hosts; rather, the climate is the main driver of their distribution patterns. Except for some monogenic species, ticks regularly feed on a wide range of hosts. Permanent foci of some tick-transmitted pathogens are restricted to the range of key reservoirs or vectors.

### 2.10.5 Burden in India

There has been suspicion of CCHFV presence in India due to confirmed CCHF positive cases in adjoining countries like Pakistan, China, and Afghanistan. The first confirmed outbreak of CCHF in India occurred in January 2011, in a tertiary care hospital in Ahmadabad, Gujarat state. Out of a total of six cases reported, contact transmission occurred to three treating medical professionals, all of whom succumbed to the disease. During the investigation presence of CCHFV in *Hyalomma anatolicum* ticks and livestock was detected in the village from where the primary case was reported. Investigations revealed the circulation of Tajikistan strain of CCHF virus in this outbreak. A retrospective investigation confirmed two CCHF human cases in Rajkot village 20 kilometres to the west of Ahmadabad during February 2010, and CCHF presence in the livestock 200 kilometers to the north in the neighboring state Rajasthan (Mourya et al., 2012).

**Table- 10: CCHF cases reported from India (Mourya et al., 2019)**

| Year | Cases | Deaths | State |
|---|---|---|---|
| 2011 | 6 | 4 | Gujarat |
| 2012 | 4 | 2 | Gujarat |
| 2013 | 18 | 7 | Gujarat |
| 2014 | 3 | 3 | Gujarat |
| 2014 | 1 | 0 | Rajasthan |
| 2015 | 4 | 4 | Rajasthan |
| 2015 | 1 | 1 | Uttar Pradesh |
| 2015-18 | Many cases | Many deaths | Gujarat |
| 2019 | Many cases | Many deaths | Gujarat & Rajasthan |

A total of 125 confirmed cases with 53 deaths (case fatality rate 42.40%) are reported from 2011 to 2020 as per NIV records (Mourya et al., 2021). The districts affected are Ahmadabad, Rajkot, Surendranagar, Amreli, Kheda, Jamnagar, Pathan, Kutch, Aravalli, Botad, Morbi and Bhavnagar in Gujar, Sirohi, Jodhpur and Jaisalmer in Rajasthan and Moradabad in Uttar Pradesh. In addition to this, in 2016 an Indian migrant worker who returned from Muscat, Oman to Kutch, Gujarat was confirmed as an imported CCHF case. Another imported CCHF case with a travel history from Dubai, The United Arab Emirates to Thrissur, Kerala, was confirmed in December 2019 (Table- 10).

During 2013-14, a country-wide survey of CCHF antibodies was carried out with samples from bovine, sheep and goats from 22 states and one Union Territory. The results showed the prevalence of this antibody in all the areas studied.

### 2.10.6 Global burden

Crimean-Congo hemorrhagic fever has been recognized for many years in central Asia and Eastern Europe. However, this recognition was just the tip of the iceberg. Today the disease is known to extend from China through central Asia to India, Pakistan, Afghanistan, Iran, Iraq, and other countries of the Middle East, Eastern Europe, and most of Saharan and sub-Saharan Africa (Figure- 36). In recent years, there have been repeated outbreaks in the countries of the Persian Gulf, especially in connection with traditional sheep slaughtering and butchering practices. Despite the rapidly growing incidence of the disease, there are currently no accurate data on the burden of the disease due to the different surveillance systems used for CCHF.

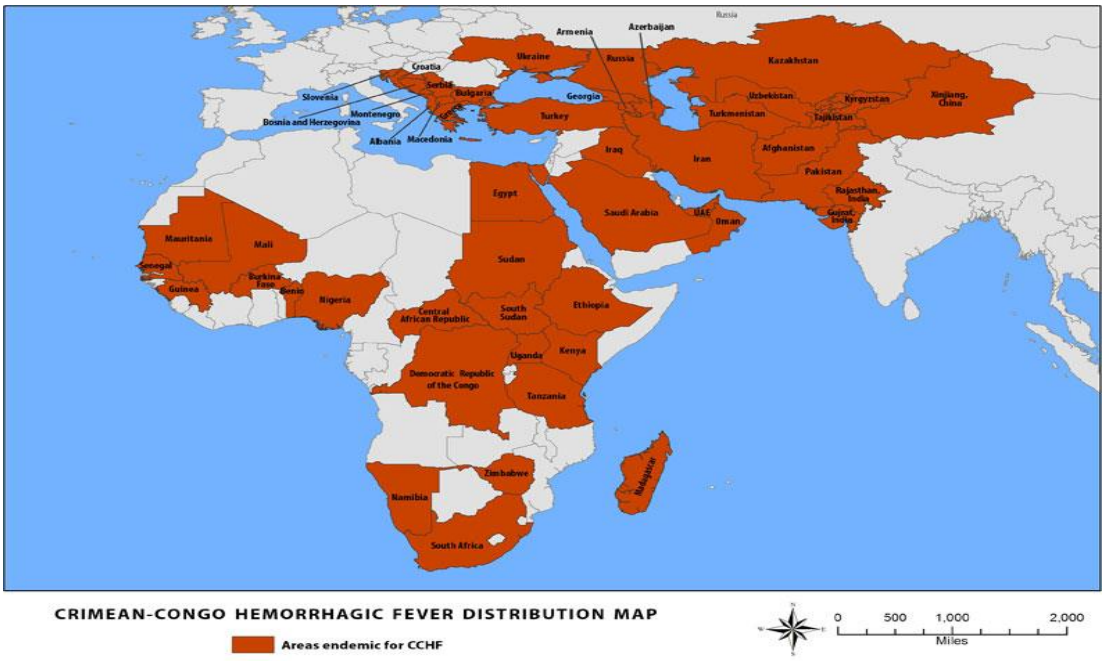



**Figure- 36: Global distribution of CCHF (Owaysee et al., 2019)**

The probable reasons for the expansion of CCHF are due to the interplay of complexity of factors related to deforestation, human settlement in forest biotopes, migratory human movements, weather changes, global warming and increasing distribution of the main vector *Hyalomma* spp. Improved surveillance and early warning systems, enhanced diagnostic facilities for early diagnosis and timely undertaking of appropriate control measures are very much needed for the successful containment of the disease.

## 2.11 KYASANUR FOREST DISEASE (KFD)

### 2.11.1 Introduction

Kyasanur Forest Disease (KFD) is one of the tick-borne diseases, which is caused by KFD virus of the genus *Flavivirus* where *Haemaphysalis spingera* is the vector. It was first discovered in Kyasanur forest of Shimoga district in Karnataka, India in 1957. It derives its name from the forest range where the virus was first isolated. It is also known as "monkey disease/monkey fever" because of its association with monkey deaths. KFD is a re-emerging zoonotic disease with associated symptoms like frontal headache, severe prostration, high fever and conjunctivitis, bleeding from the nose, mouth, and gastrointestinal tract. The disease in men is often fatal unless recognized early and treated symptomatically and prompt laboratory investigations. The Case Fatality Rate (CFR) is about 5 to 10%. KFD is a seasonal disease mainly reported during early and peak summer months occurring in endemic and other forest-fringed areas during the transmission period.

### 2.11.2 Causative agent and vector

The KFDV is a single-stranded RNA genome of positive polarity. Hard ticks belong to the Family Ixodidae of the genera Haemaphysalis are vectors and reservoirs of KFD virus. The eggs are laid in the forests either under the litter, dry leaves or vegetation in the soil. They are laid in clusters consisting of a very large number, sometimes a few thousand. The ovipositioning lasts for several days, usually about a fortnight, but in some cases, may extend to one month or more. All *Haemaphysalis* spp. have three-host ticks i.e. larvae, nymph and adult stages feed three different hosts and transmit the virus by transstadial mode. *H. spinigera* is the main vector of KFD, which is endemic in Karnataka state, India. Among other susceptible species of *Haemaphysalis* are *H. turturis*, *H. papuana kinneari*, *H. minuta*, *H. cuspidata*, *H. bispinosa*, *H. kyasanurensis*, *H. wellingtoni* and *H. aculeate*. Transmission of KFDV in the laboratory has been demonstrated in a number of *Haemaphysalis* and *Ixodes* species.

### 2.11.3 Transmission

KFD is transmitted to any human by the bite of an infected tick and especially nymphal-stage ticks. It is transmitted almost exclusively by larvae and nymphs of *H. spinigera*, and in the absence of natural transovarial transmission of the virus in this species, transmission may occur by bite of infected nymphs. The wild monkeys *Semnopithecus entellus* and *Macaca radiata*, gets the disease through the bites of infected ticks. The infection causes severe

febrile illness in most of monkeys. When infected monkeys die, the ticks drop from their body, thereby generating "hotspots" of infectious ticks that further spread the disease. The eggs are laid in the forests either under the litter or in the cracks, crevices and other such holes in the soil. They are laid in clusters consisting of a very large number, sometimes a few thousand. The egg laying process lasts for several days, usually about a fortnight, but in some cases, may extend to one month or more. Humans can get infected either from an infected tick bite or by contact with an infected animal. Ticks have also been found to transmit this virus transstadially, thus also acting as a reservoir for the virus. Nymphs and adults also transmit the disease to rodents and rabbits and this rodent-tick cycle continues for more than one life-cycle (Figure- 37).

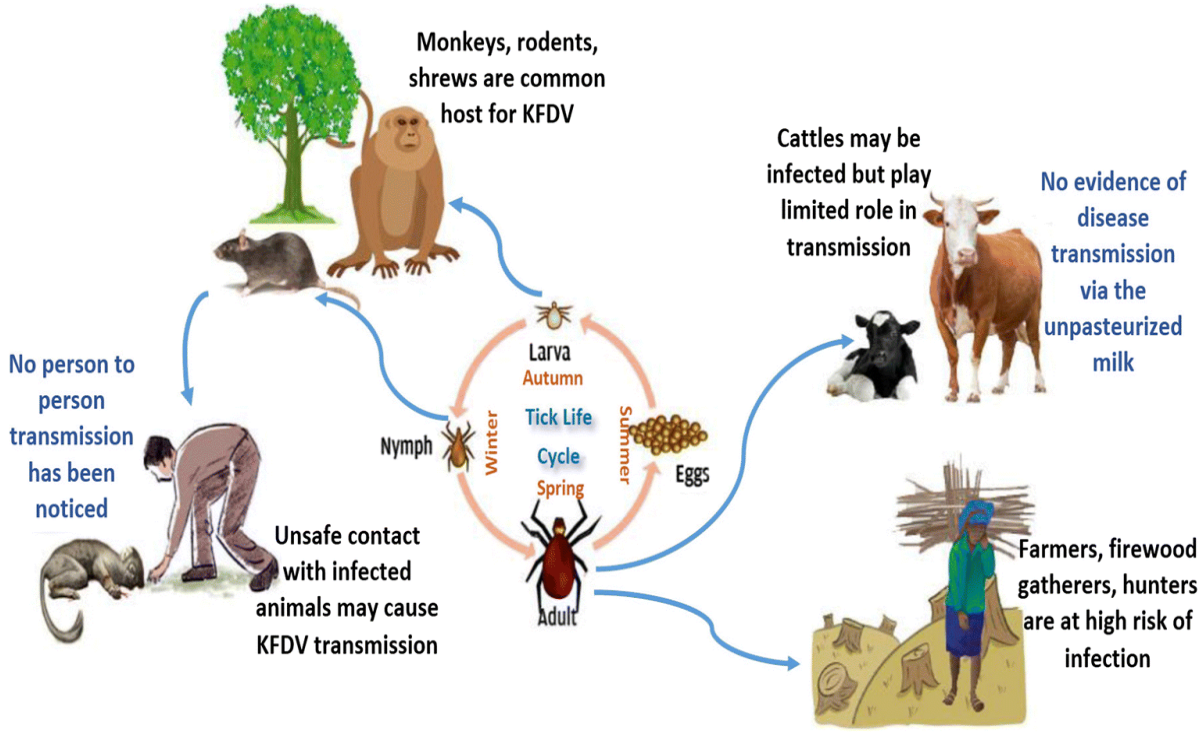



**Figure- 37: Transmission cycle of KFD (Majumdar et al., 2018)**

### 2.11.4 Epidemiology

The disease was first noted at Kyasanur village near Sagar in Shivamogga district of Karnataka. The epidemic period usually begins in October or November and peaks from January to April, then declines by May or June. The epidemic/outbreaks relate to the activity of nymphs, which is very high from November to May. Adult female ticks lay eggs after feeding, eggs hatch to larvae under the leaves.

**Maintenance of natural enzootic cycle**: A number of forest-dwelling small mammals like rodents, shrews, porcupines, insectivorous bats and many ground birds maintain the natural enzootic cycle of the virus in the forest ecosystem. The black-faced langur (*Presbytis entellus*) and the red-faced bonnet monkey (*Macaca radiata*) act as sentinel animals, as they are very susceptible to KFDV like humans. Epizootics of this infection cause a heavy burden of mortality in these monkeys, which indicates likely outbreaks. The virus has been detected in autopsy of the dead monkeys in forests and forest-fringed villages during winter and summer months. Ticks drop as soon as the animal dies, thus generating hotspots for infection. The virulence of KFDV is noticeable; numerous infections were reported in laboratory and field personnel who were directly dealing with a KFD outbreak.

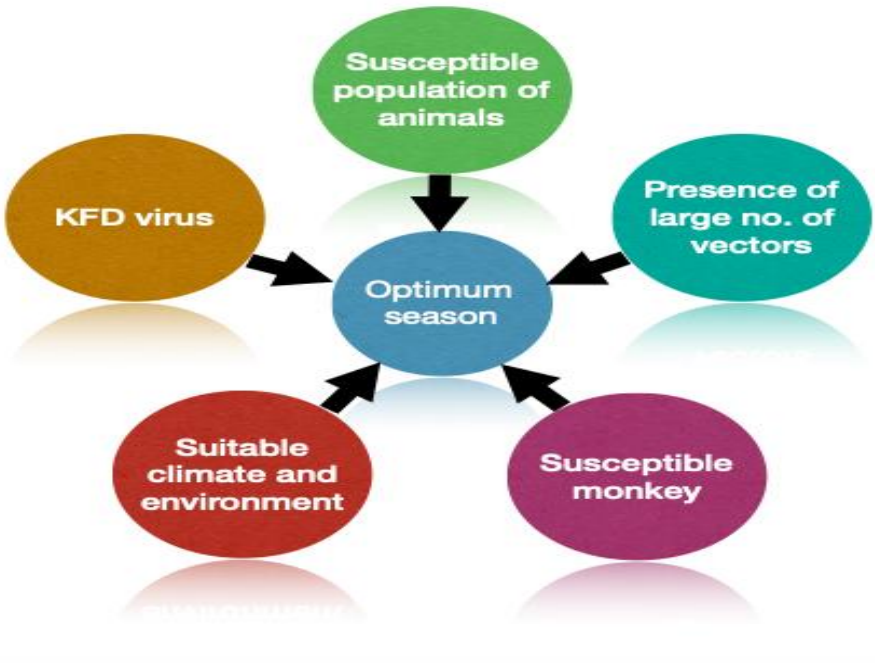



**Figure- 38: Factors responsible for KFD**

Biotic and abiotic factors, climatic niche characterization and tick-pathogen interactions (Figure- 38) all play an important role in tick distribution across different geographical regions of the world. Along with chemical control, biological control methods by the assistance of natural predators like spiders, beetles, and nematodes can be another alternative approach based on integrated pest management.

### 2.11.5 Burden in India

The disease was first reported from Shimoga (now Shivamogga) district, Karnataka, which is a primitive sylvan territory in the Western Ghats of India, subsequently spread centripetally

to other districts of Karnataka viz., Chikkamagalore, Uttara Kannada, Dakshina Kannada and Udupi districts. The disease spread to Chamarajanagar district in 2012 and most recently to Belagavi district in 2016. The Western Ghats provide ideal topographical and climatological conditions for the vector ticks, thus making these Ghats as an epitome for this tick-borne disease. The Western Ghats cover 1600 km area starting from south of the Tapti River (near the border of Gujarat and Maharashtra) and the pass-through States of Maharashtra, Goa, Kerala, Karnataka and Tamil Nadu (Figure- 39).

There is a high risk of the spread of KFD amongst the people working/living in and around forest areas of these regions. Movement of monkeys and rodents also contributes, since they harbour vector ticks, which maintain the KFD virus in nature by transovarial and transstadial transmission.

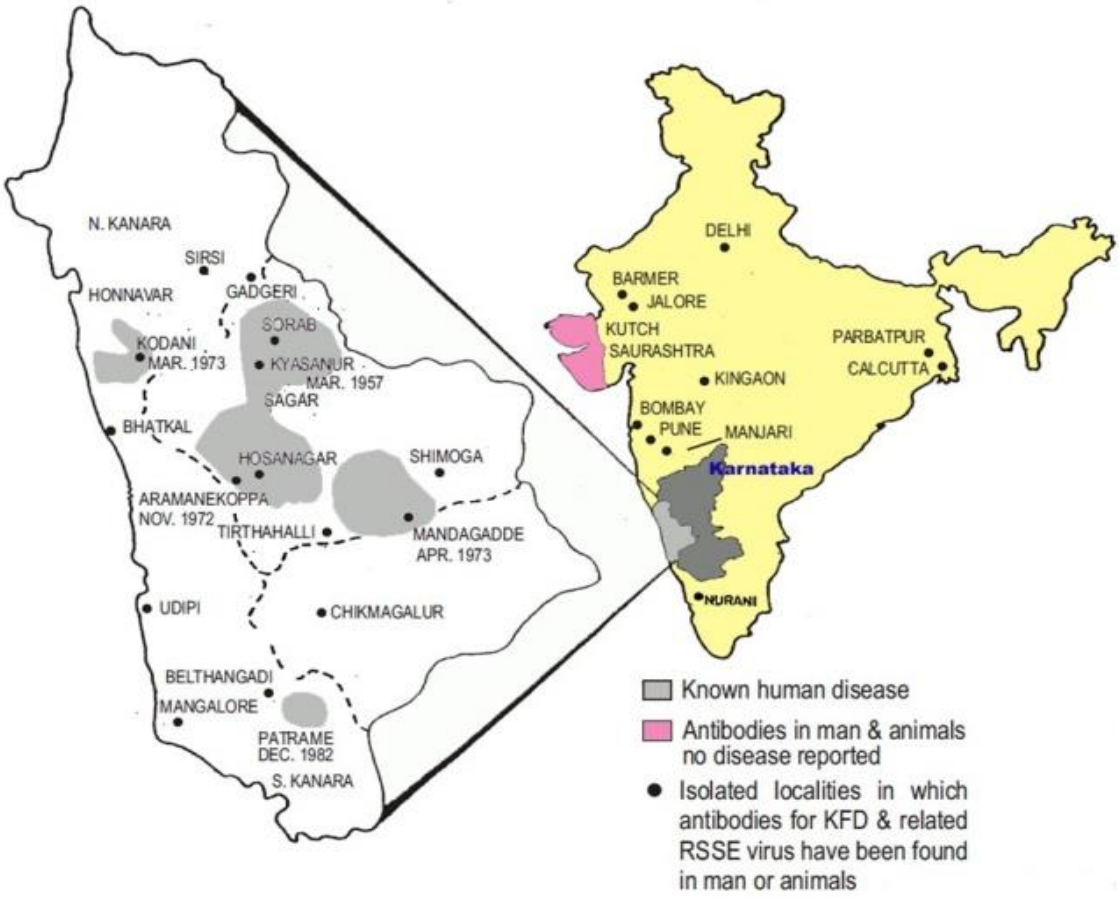



**Figure- 39: Regions affected by KFD in India (ICMR)**

During the initial outbreak, there were 466 human cases and 181 more the following year (Acha and Szyfres, 2003). The disease is common in young adults that have been exposed during the dry season in the forest, and it has caused epidemic outbreaks of hemorrhagic

fever affecting 100 to 500 people per year since then, with a case fatality rate between 2-10% (Acha and Szyfres, 2003; Heymann, 2004; Brown et al., 2005; Gould and Solomon, 2008). During 2014-2015, KFD outbreaks were explicitly observed in new regions of Wayanad and Malappuram districts of Kerala; and recently, KFD activity has been reported in Goa, India. It is evident that the KFDV is centripetally spreading to newer areas. At present apart from the Karnataka state, KFD has been reported in four neighbouring states viz., Kerala, Tamil Nadu, Goa and Maharashtra. These newly reported localities situated in the Western ghats track having similar topography where extensive deforestation and conversion of land into monoculture plantations prevails. The KFD virus occurrence in India during the period in between 2012-16 has shown in Table- 11.

**Prevention and control of outbreaks of KFD:** In monkey death localities health education to the community is very much essential by advising people to avoid such areas in the forest. Persons need to visit the forest, should cover their body with thick cloths and topical application of tick repellants like DMP oil, in order to avoid tick bites. All monkey deaths in the forest and adjoining villages should be reported to the local health authorities for further investigations and to undertake insecticidal treatment of the area of hot spot

Vaccination is a key role in the prevention of KFD cases. The criteria for selecting the KFD active areas are viz., laboratory-confirmed human case; reported monkey death; or hard tick positive for KFD virus. The vaccine is administered to the target age group of 6-65 before the onset of KFD season. The vaccination is by the administration of two primary doses followed by a Booster dose every year,

Insecticide treatment in Hot spots: Malathion powder is dusted in the ground for 50 meters radius in and around monkey death hot spot areas. Treatment of house / hut if situated in the forest or on the periphery of hot spot by indoor residual spray. For long-term measures tick control of *H. spinigera* on cattle's bodies by using Acaricides. Spraying of forest ground should be done along the tracks frequently used by villagers.

**Table- 11: Occurrence of KFD virus reported in India**

| Occurrence of KFD Virus reported in India during 2012-16 | |
|---|---|
| **2012** | 100 confirmed cases in Karnataka; tick and monkey positivity |
| **2012** | KFDV confirmed in a monkey in Nilgiri, Tamil Nadu |
| **2012–13** | Outbreak in the Bandipur National Tiger Reserve, Karnataka; confirmed by human 13 and monkey positivity |
| **2013** | Human case confirmed in Wayanad, Kerala |
| **2014** | Outbreak in seven health centres in Thirthahalli, Shimoga, Karnataka |
| **2014** | Human case confirmed in Wayanad, Kerala |
| **2014** | Outbreak in a tribal population, Malappuram, Kerala |
| **2014** | Anti-KFD IgG antibody positivity in a tribal population of the Palakkad and Wayanad districts, Kerala |
| **2015** | Confirmed in monkey specimens in Nilambur, Malappuram, Kerala |
| **2015** | Tick positivity for KFDV in Wayanad, Kerala |
| **2015** | Outbreak in Wayanad, Kerala [18 confirmed cases; Pulpally (7), Mullankolly (8), Chethayalayam (1), and Poothadi (2)] |
| **2015** | Outbreak in Shimoga, Karnataka [35 confirmed cases] |
| **2015** | Outbreak in Pali village, Sattari Taluka, northeast Goa [18 confirmed cases] |
| **2016** | Outbreak reported from Sindhadurg district of Maharashtra and Belagavi district of Karnataka |

### 2.11.6 Global burden

The family *Flaviviridae* includes several tick-borne viruses affecting humans. The KFD virus was initially suspected as a Russian spring-summer (RSS) complex of viruses. As of now, KFD is only reported from India. The other viruses, which are closely related to KFD are Tick-borne encephalitis virus (TBEV) and Far-eastern TBE, and include Omsk hemorrhagic fever virus in Siberia Omsk hemorrhagic fever virus in Siberia. In USA and Russia, another tick-borne flavivirus, Powassan virus, is responsible for encephalitis in human. Recently reported other tick-borne viral diseases Alkhurma virus in Saudi Arabia and Nanjianyin virus in China are closely related to, Kyasanur Forest Disease virus and are similar to Russian Spring-Summer Encephalitis virus (RSSEV).

## 2.12 Chandipura Virus (CHPV)

### 2.12.1 Introduction

Chandipura Virus (CHPV) infection is an arthropod-borne viral fever caused by a virus of the Rhabdoviridae family and genus *Vesiculovirus* called as chandipura virus. It was discovered in 1966 by Bhatt and Rodriguez, at Virus Research Centre (VRC), Pune. It was found accidentally while investigating patients suffering from fever in Chandipura village in northern Maharashtra near Nagpur district, for dengue or chikungunya virus etiology, and was thus named Chandipura Virus as *Chandipura vesiculovirus* (Walker, 2015) after the geographic location of its discovery (Bhatt and Rodrigues, 1967). The clinical picture of patients infected with CHPV is not very clear. It varies from the high-grade fever of short duration, vomiting, altered sensorium, generalized convulsions and decerebrate posture leading to Grade IV coma to acute encephalitis or encephalopathy, and death within a few hours to 48 hours of hospitalization (Rao et al., 2004).

### 2.12.2 Causative agent and vector

Chandipura Virus (CHPV) is a negative-stranded RNA virus, rod-shaped or the typical bullet-shaped, 150-165 nm long, 50-60 nm wide comprising a nucleocapsid covered with a lipid envelop (Figure- 41) and nucleic acid composition (as having a single-stranded RNA genome of negative sense). It shows distinct surface projections, 9 to 10 nm size and a stain-filled canal at the base of the virus particle. Chandipura virus belongs to the genus *Vesiculovirus* placed in the order of Mononegavirales of Rhabdoviridae family.

**Figure- 40: *Phlebotomus papatasi* (Sandfly)**

*Vesiculovirus* is called as chandipura virus and the vector is the female sandfly, *Phlebatomus papatasi* (Figure- 40). The virus has been detected in *Phlebotomine* sandflies in Africa, Senegal and Nigeria as well as in India during arbovirus investigations. Among the *Phlebotomine* sand flies, *Ph. papatasi* is one of the most dominant anthropophagic and domiciliary species prevalent in several parts of India (Dhanda et al., 1970). A few isolations of CHPV have been reported from wild-caught *Phlebotomine* sandflies in India.

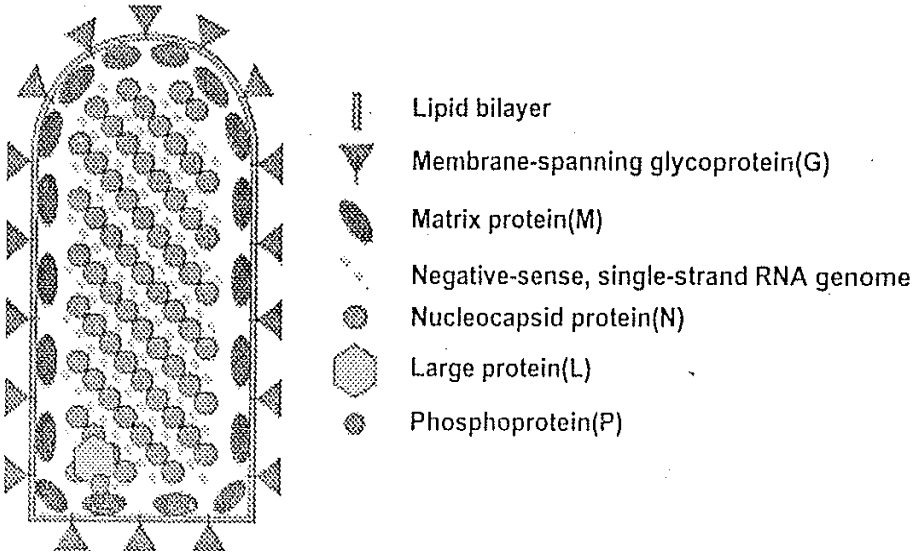



**Figure- 41: Diagrammatic representation of Chandipura virus (Zodpey and Sanzgiri, 2005)**

### 2.12.3 Transmission

CHPV is transmitted by Phlebotomine Sandflies as evidenced by repeated isolations and their ability to transmit the virus by transovarial and venereal routes (Sudeep et al., 2016). Venereal transmission is considered as one of the modes of maintenance of the virus in nature. The vertical transmission phenomenon of CHPV in *Ph. papatasi* has been already established, in which the males of *Ph. papatasi* can get infection of CHPV through vertical transmission (transovarial). These vertically infected males can transfer the CHPV to females by venereal route *i. e.* venereal transmission (horizontal transmission). Previously uninfected females could get an infection after mating with CHPV-infected males (Mavale et al., 2006). It is demonstrated that venereal transmission of arboviruses by its arthropod vectors might serve as one of the mechanisms for horizontal transmission. It is also indicated the possible occurrence of vertical and venereal transmission of CHPV in insect vectors. In nature, infected males are capable of passing on the virus to female sandflies while mating.

The CHPV completes its life cycle in a cytosolic manner within an infected cell (Banerjee 1987). The Vesiculovirus life cycle can be divided into discrete steps, namely, adsorption of the virus particle, penetration of the virus into cell, uncoating and release of core RNP into the cytosol from late endosomal vesicles, transcription of the genome by viral polymerase, translation of viral mRNA, post-translational modifications of viral proteins, replication of viral genome, assembly of progeny particles and finally budding of the mature virion (Figure-42).

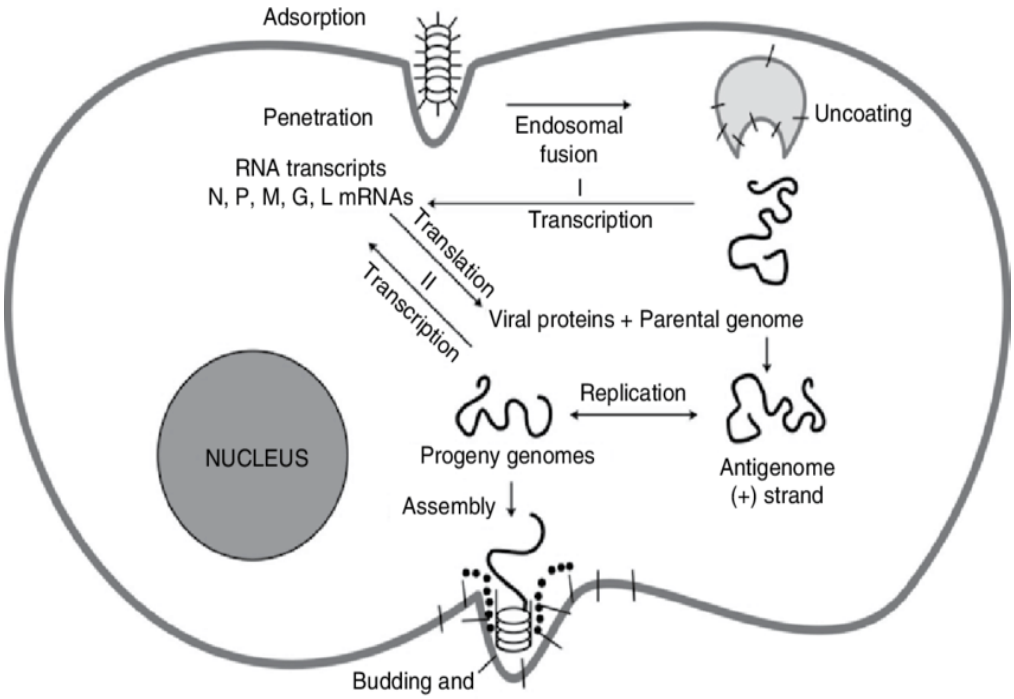



**Figure- 42: Life Cycle of Chandipura Virus**, (Bisen and Raghuvanshi, 2013**)**

### 2.12.4 Epidemiology

The causative agent Chandipura virus is a *Vesiculovirus*, described by Bhatt and Rodrigues in 1967. The virus most commonly affects children below the age group of 15 years. From the serological evidence of the outbreak in Gujarat, it is seen that a significant proportion of the pediatric population is susceptible to Chandipura virus. The presence of neutralising antibodies among the healthy population and the fact that immunity increases with age. Susceptibility is universal, relative resistance of native populations in sandfly area is probably attributable to infection early in life. There is no gender predilection. The virus most commonly affects children belonging to families with low-income groups. The virus spreads mainly through the bite of sand flies. Most commonly affected are rural areas, where houses are ill-maintained and sanitation levels are low. It is also observed that houses, which are

away from the general locality are most affected. Areas near cattle shed and poultry is said to be breeding places for the vectors and hence, source of infection. Infective bite of an infected sandfly is a mode of transmission. Nearly 30 species of Phlebotomine sandflies have been recorded for transmission of the virus. The sandfly is smaller than a mosquito and lays eggs in dark damp places in the vicinity of cattle sheds. The average life of an adult sandfly is about 15 days. Sandflies infest dwellings during the night, and take shelter during the day in holes and crevices in walls, holes in trees, dark rooms, stables and store rooms. Sandfly is the main vector as well as reservoir of Chandipura virus. The incubation period lasts for 1-2 days.

In 2003, 329 people died in an outbreak in Andhra Pradesh and Maharashtra. In 2009, the virus infected 52 people and claimed 15 lives. In 2010, a total of 50 people contracted the virus and 16 died. A majority of the infected patients were below 14 years of age. An outbreak in Gujarat in Kheda District, Vadodara District, and Panchmahal District killed 17 people in 2010. Sandfly bites are blamed as they inhabit cracks in walls or parts of homes made of sand or mud. The sporadic cases appeared in Gujarat in 2014 and 2016. One girl died in Ahmedabad in 2016. In 2019 one girl died in Bhayli village of Vadodara. An outbreak of encephalitis with a case fatality rate of 78.3% was investigated among children in Gujarat State, India.

### 2.12.5 Burden in India

CHPV was first isolated in the National Institute of Virology (NIV) in Pune, Maharashtra state, India in 1965. Further, the same entity was also isolated from sand flies during a routine entomological investigation in Aurangabad in 1967 (Dhanda et al., 1970) and subsequently, from a serum sample of a child suffering from encephalopathy in Jabalpur, Madhya Pradesh (Rodrigues JJ et al., 1983). Apart from these sporadic cases in the states of Maharashtra and Madhya Pradesh, CHPV did not gain any public health importance until 2003, when NIV in Pune investigated CHPV associated with a large encephalitis outbreak in children in many districts of Andhra Pradesh and Maharashtra, India (Rao et al., 2004). Afterwards many viral encephalitis outbreaks were found to be associated with CHPV; these include 2003 (Maharashtra and Andhra Pradesh), 2004 (Gujarat), 2005 and 2007 (Maharashtra and Andhra Pradesh) (Rao et al., 2004; Chadha et al., 2005). Some evidence suggests the existence of CHPV for more than 50 years, although CHPV has recently attained the status of an important emerging pathogen of public health and the distribution of Chandipura virus in

various Indian states. In 2010, an outbreak in Kheda, Vadodara, and Panchmahal districts of Gujarat state.

### 2.12.6 Global burden

Chandipura virus (CHPV) can infect many mammalian species in different places throughout the world (Figure- 43), but human cases have only been reported in India. Retrospective analysis revealed that this virus is highly prevalent in India (Bhatt and Rodrigues, 1967), Sri Lanka (Peiris et al., 1993), and Africa in Nigeria and Senegal (Fontenille et al., 1994; Traore-Lamizana et al., 2001).

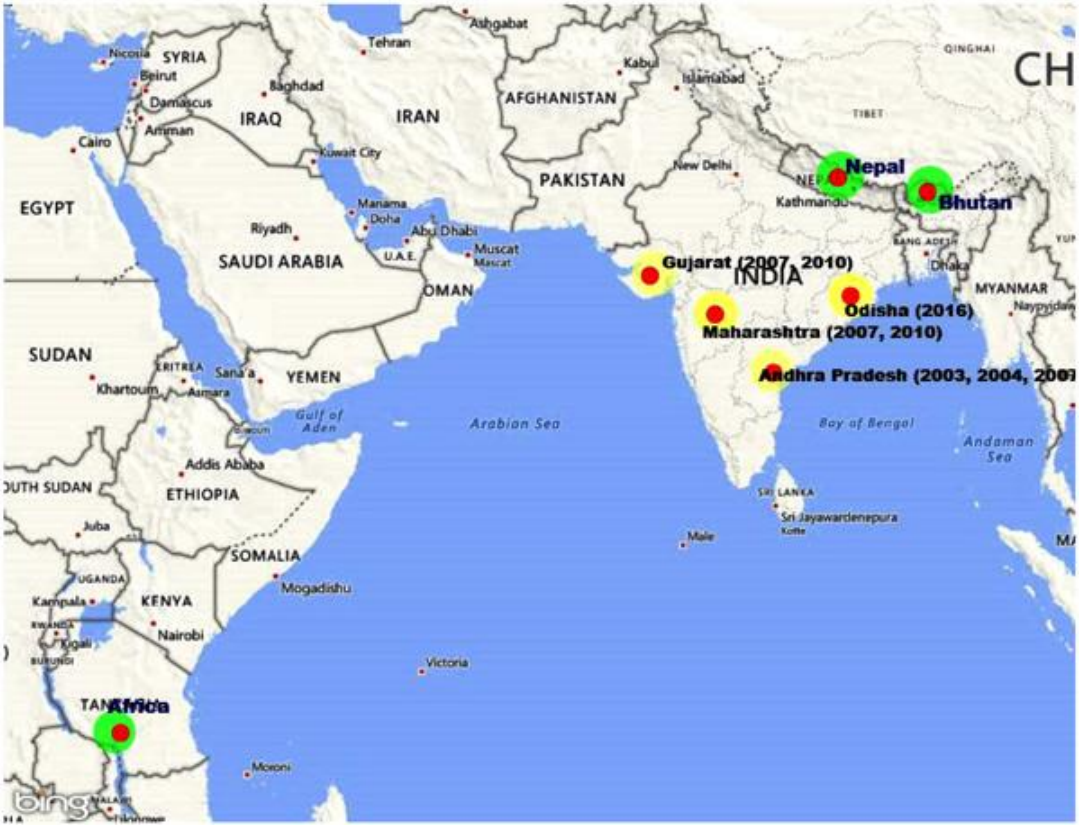



**Figure- 43: Distribution of Chandipura Virus (Sapkal et al., 2018).**

It was also found in pools of 253 unidentified sand flies (*Phlebotomus* sp.) caught in human dwellings and cowsheds in Maharashtra, India. Neutralizing antibodies to CHP virus have been detected in camels, horses, buffaloes, sheep, goats, Rhesus and other monkeys. Chandipura virus has also been isolated in Nigeria from hedgehogs and from humans. The Senegalese strain was the first isolate of the virus from arthropods in Africa. The presence of the virus in Africa indicates a wide distribution although no human cases have been observed outside India.

## 3. Glossary

**Acetylcholinesterase**

Acetylcholinesterase is a type-B carboxylesterase enzyme located primarily in the synaptic cleft with a smaller concentration in the extra junctional area.

**Active ingredients**

An active ingredient is the element or substance in an insecticide that gives repelling or killing power or biologically active.

**Adulticides**

Type of insecticides used to kill adult insects or pests.

**Alkaloids**

Cyclic organic compound containing nitrogen in a negative oxidation state, which is of limited distribution among living organisms.

**Adult susceptibility test**

Adult susceptibility bioassay is a direct response-to-exposure test; it measures mosquito mortality to a known standard dose of a given insecticide (*i.e.*, the diagnostic or discriminating concentration).

**Advocacy**

Advocacy is a process by an individual or group, which aims to influence public policy and resource allocation decisions within political, economic, and social systems and institutions. Advocacy can include many activities that a person or organization undertakes including media campaigns, public speaking etc.

**Aerosol**

An aerosol is a suspension of small particles in air or another gas.

**A*f*I**

Annual *falciparum* Incidence is calculated as total positive *Plasmodium falciparum* in a year x 1000 divided by total population.

**Antibody**

Antibodies are substances, which are formed in the serum and tissue fluids in response to an antigen and react with that antigen specifically and in some observable manner.

**Antibiotic**

Antibiotics are molecules that kill or stop the growth of, microorganisms, including both bacteria and fungi.

**Anganwadi**

It is a rural child care center in India, providing care for mothers and young children in a rural area.

**API**

The Annual Parasite Incidence (API) is a malariometric index to express malaria cases per thousand population. API refers to high and moderate malaria transmission risk areas.

**Arbovirus**

A virus that multiplies in a blood-sucking arthropod and is principally transmitted by the bite of arthropods to vertebrate hosts.

**ASHA**

Accredited Social Health Activist (ASHA) is one of the key components of the national health mission (earlier national rural health Mission), which provides every village in the country with a trained female community health activist.

**Aldrin**

A brown, water-insoluble, toxic solid consisting of more than 95 percent of the chlorinated hydrocarbon C12H8Cl6: is used as an insecticide.

**Alpha-cypermethrin**

Alpha-cypermethrin is a pyrethroid insecticide consisting essentially of two of the four cis isomers comprising

cypermethrin. Alphacypermethrin is a highly active broad-spectrum insecticide, effective by contact and ingestion against target pests.

**Amastigotes**

The nonmotile, parasitic form in the life cycle of some protozoans and especially Leishmania that usually develops in the cells of vertebrate hosts and occurs as a minute, ovoid or spherical body with a prominent, rod-shaped kinetoplast and a rudimentary, internal flagellum arising from a basal body.

**Amplifying hosts**

It is a host in which infectious agents multiply rapidly to high levels, providing an important source of infection for vectors in vector-borne diseases.

**Anthropogenic factors**

Anthropogenic factors of the environmental changes influence the organic world and are introduced into nature by human activity. In reworking nature and adapting it to their own needs, people influence the lives of animals and plants by altering their habitats. The influence may be indirect or direct.

**Anthropophilic**

Anthropophilic is associated with humans or attracted to humans, especially for food sources.

**Antibodies**

Antibodies are substances, which are formed in the serum and tissue fluids in response to an antigen and react with that antigen specifically and in some observable manner.

**Antigens**

An antigen is a substance that, when introduced into a body evokes an immune response to produce a specific antibody with which it reacts in an observable manner.

**API**

The Annual Parasite Incidence (API) is a malariometric index to express malaria cases per thousand population. API refers to high and moderate malaria transmission risk areas.

**Arbovirus**

Arbovirus is an arthropod-borne virus. A virus that multiplies in a blood-sucking arthropod and is principally transmitted by the bite of arthropods to vertebrate hosts.

**Arthropods**

An animal of the phylum Arthropoda, characterized by the presence of a segmented body, an exoskeleton, jointed appendages, a dorsal blood vessel, a haemocoel and a ventral nerve cord.

**Aspirator**

It is a device to collect small insects and other invertebrates. The aspirator is having one tube through which they are sucked into the bottle, and another, protected by muslin or gauze, which sucks insects.

**Autochthonous**

Originating or formed in the place where found; indigenous.

***Bacillus thuringiensis***

*Bacillus thuringiensis (Bt)* is an aerobic, spore-forming, gram-positive, rod-shaped bacterium distributed widely in the natural environment. It's used to control mosquito larvae as known as larvicide or bacterial larvicide.

**Bacteria**

Bacteria are prokaryote single-celled micro-organisms with a simple nucleus intermediate in size between protozoa and rickettsia.

**Bacterial larvicides**

The bacteria like *Bacillus thuringiensis* var. *israelensis* and *Bacillus sphaericus* have been used extensively for mosquito control and be effective and safe for non-

target organisms cohabiting with mosquito larvae.

**Bait**

Bait is the active placement or manipulation of edible or inedible items, to attract or distract potential prey, facilitating prey capture.

**Bancroftian filariasis**

Bancroftian filariasis is a disease caused by a nematode of the genus *Wuchereria*, that is transmitted in larval form by mosquitoes.

**Behaviour Change Communication**

The changes that the intended audiences are expected to make in their behaviour and the expected changes in the factors that influence behaviour such as knowledge, attitudes and perceptions.

**BG-sentinel trap**

The BG-Sentinel mosquito trap is essentially a collapsible, fabric container with a white lid with holes covering its opening. In the middle of the gauze cover, the air is sucked into the trap through a black catch pipe by an electrical fan, drawing approaching mosquitoes into a catch bag.

**Bioassay**

Bioassays are methods that utilize living materials to detect substances or determine the potential toxicity of chemicals or contaminated matrices. They are widely used to screen for potentially hazardous chemicals in contaminated soils, potable and wastewater, foods, and other materials.

**Biological control**

Deliberate introduction of biological agents such as pathogens, parasites and predators (especially fish) to control arthropod population.

**Bioaccumulation**

Bioaccumulation is defined as the accumulation of chemicals in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, and pore water in the sediment

**Biodegradation**

Biodegradation means that the decaying of all organic materials is carried out by a huge assortment of life forms comprising mainly bacteria and fungi, and other organisms.

**Botanical larvicides**

The plant products used to kill or control mosquito larvae are called botanical larvicides.

**Botanical pesticides**

The plant products used to kill or control the pest are called botanical pesticides.

**Bristles**

A large seta or short stiff coarse hair or filament.

***Brugia malayi***

*Brugia malayi* is a nematode, filarial worm, one of the causative agents of Brugian filariasis in humans.

**Canals**

Canals are artificial (manmade) channels, generally regular in shape, which are constructed to convey water to the farm fields from a river or reservoir.

**Capitulum**

Anterior body of mites and ticks including the mouthparts (also commonly known as the gnathosoma).

**Capsule suspension**

Capsule suspensions are water-based slow-release formulations containing active ingredients encapsulated inside polymer microcapsules. The CS formulations are very useful to provide a prolonged effect for controlling target pests.

**Carbamates**

Synthetic insecticides are derivatives of carbamic acid, e.g., carbaryl and propoxur.

**Carcinogens**

The term "carcinogen" denotes a chemical substance or a mixture of chemical substances, which induce cancer or increase its incidence.

**Chelicera**

The paired piercing appendages present as mouthparts of mites and ticks.

**Chemical control**

The use of chemicals to disrupt the life cycle of vectors at different stages of their life cycle is known as chemical control.

**Chemosterilant**

Chemicals used to induce sterility, but not usually death, in arthropods to control them, e.g., *apholate* and *tepa*. Chemo Sterilized insects are sometimes used in the genetic control of insect vectors.

**Chemoprophylaxis**

Chemoprophylaxis is the administration of drugs to prevent the development of a disease.

**Claws**

A hooked structure curved at the end of the leg of an insect, which is usually paired.

**Climate**

Climate is the average weather condition of the earth's surface over a long period of time, taking into account temperature, precipitation, humidity, wind, barometric pressure, and other phenomena.

**Clypeus**

Clypeus is the area of the facial wall of an insect's head between the labrum and the frons, usually separated from the latter by a groove.

**Cocoon**

Cocoon is the protective formation of the pupae of many insects. The cocoon is usually woven of silk thread secreted by the larva before pupation.

**Cold fogs**

With cold fogs the droplets are formed by the mechanical breaking up of the spray mixture, either by passing it through high-pressure nozzles or by passing a slow stream of the mixture through a high-velocity vortex of air.

**Collaboration**

It is a process in which entities share information, resources, and responsibilities to jointly plan, implement and evaluate a program of activities to achieve a common goal.

**Community**

Community is a group of people with diverse characteristics who are linked by social ties, share common perspectives, and engage in joint action in geographical locations or settings.

**Communicable diseases**

Communicable diseases spread from one person to another or from an animal to a person through any medium. The spread often happens via airborne viruses or bacteria, but also through blood or other bodily fluid.

**Congenital malaria**

Congenital malaria, occurring as a result of vertical transmission of parasites from mother to child during pregnancy or prenatally is a rare clinical condition. It occurs as a consequence of clinical attacks of malaria during pregnancy but also may be detected rarely in infants of asymptomatic women, where the diagnosis may be missed.

**Concentration**

The amount of solute dissolved in a unit amount of solvent.

**Conventional SIT**

Mass rearing of mosquitoes followed by manual sex separation to assure that exclusively males are to be sterilized by ionizing radiation and further released to mate with wild females resulting in no progeny.

**Conjunctivitis**

Conjunctivitis refers to any inflammatory condition of the Conjunctiva. It is the most common cause of "red eye". Virus and bacterial conjunctivitis is the most common cause of infectious conjunctivitis.

**Crystal protein**

Crystal proteins made by the bacterium *Bacillus thuringiensis* (*Bt*) are pore-forming toxins that specifically target invertebrates (insects and nematodes) and are generally innocuous to mammals.

**Cytoplasmic Incompatibility**

Cytoplasmic incompatibility occurs when factors in the cytoplasm of the two gametes are not compatible, resulting in the death of the zygote.

**Death rate**

Death rate or mortality rate is a measure of the frequency of occurrence of death in a defined population during a specified interval.

**Definitive host**

Host in which parasites reach to maturity. This rarely occurs in arthropod vectors, but the noted exception is the development of malarial parasites, involving sexual reproduction, in mosquitoes. See Intermediate host.

**Degeneration**

A morbid change consisting in a disintegration of tissue/in substitution of a lower form for a higher form of structure

**Deltamethrin**

Deltamethrin is an insecticide belonging to the pyrethroid family. Pyrethroids are man-made versions of pyrethrins, natural insecticides from chrysanthemum flowers.

**Demography**

Demography is the study of human populations with respect to their size, structure and dynamics.

**Dengue Virus (DENV)**

The dengue virus (comprises four distinct serotypes- DEN-1, DEN-2, DEN-3 and DEN-4), which belonging to the Genus Flavivirus, family Flaviviridae.

**Deutonymph**

It is the second nymph stage of a mite.

**Dieldrin**

Dieldrin is an organochlorine compound resulting from the epoxidation (carbon-carbon double bond into oxiranes) of the double bond of aldrin. It is the active metabolite of the pro insecticide aldrin. It has a role as a xenobiotic and a carcinogenic agent. It is an organochlorine insecticide, an organochlorine compound and an epoxide. It derives from aldrin.

**Diflubenzuron**

Diflubenzuron is a direct-acting insecticide normally applied directly to plants or water against mosquito and noxious fly larvae.

**Disability**

A physical or mental condition that limits a person's movements, senses or activities.

**Disease morbidity**

Morbidity is the state of being symptomatic or unhealthy for a disease or condition. It is usually represented or estimated using prevalence or incidence.

**Distribution**

In epidemiology, distribution means the frequency and pattern of health-related characteristics and events in a population.

**Dominant lethal**

A dominant lethal mutation occurs in a germ cell and results in the death of the fertilized egg or developing embryo.

**Dose**

Dose is a quantity of an insecticide,

medicine or drug taken or recommended to be taken or used at a particular time.

**Ecological interrelationships**

Ecological interrelationships describe the interactions between and among the organisms within their environment.

**Ecology**

Ecology is the study of the interaction between living organisms, including humans, and their physical environment.

**Ecosystem**

The living community of plants and animals in any area together with the non-living components of the environment such as soil, air and water, constitute the ecosystem.

**Ecosystem integrity**

Ecosystem integrity is defined as the system's capacity to maintain structure and ecosystem functions using processes and elements characteristic of its eco region.

**Electric vaporizer**

Electric vaporizers enable harmful flies and mosquitoes to be removed from indoor spaces owing to the vaporization of the natural and herbal volatile oils in liquid form by means of electricity.

**Emulsifiable Concentrate**

Emulsifiable concentrates are typically optically transparent oily liquid formulations that are prepared by dissolving a certain amount of pesticide in organic solvents (such as benzene, toluene, xylene and solvent oil), which may also contain surfactants and other additives. These systems are then diluted with water before application, which leads to the spontaneous formation of an oil-in-water emulsion that contains pesticides inside the oil droplets.

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**Endemic**

Endemic refers to the constant presence or usual prevalence of a disease or infectious agent in a population within a geographic area.

**Endocrine disruption**

An endocrine disruptor is an exogenous substance or mixture that alters the function (s) of the endocrine system and consequently causes adverse health effects in an intact organism, its progeny, or population.

**Endophagic**

An insect that feeds indoors.

**Endophilic**

Insects, such as some mosquitoes, tend

to inhabit or rest indoors before or after blood-feeding.

**Endosymbiont**

Endosymbionts are organisms that form a symbiotic relationship with another cell or organism.

**Endrin**

Endrin is a white crystalline, odourless solid dissolved in a liquid carrier. It is water emulsifiable. Endrin is used as a pesticide to control insects, rodents, and birds.

**Entomological surveillance**

Periodic collection of data related to knowledge of local vector species and their susceptibility to insecticides, as well as on vector and human behaviors that may allow mosquitoes to avoid contact with interventions and thereby maintain residual transmission, which is essential to inform vector control strategies and track their impact on disease.

**Entomology**

Entomology is the science dealing with the scientific study of insects.

**Environment**

Environment is a complex of many variables, which surrounds man as well as living organisms. The environment includes water, air and land and the interrelationships, which exist among and between water, air and land and human beings and other living creatures such as plants, animals and microorganisms.

**Environmental management**

Environmental management consists of actual decisions and action concerning policy and practice regarding how resources and the environment is appraised, protected, allocated, developed, used, rehabilitated, remediated and restored.

**Environmental Modification**

A form of environmental management consisting in any physical transformation that is permanent or long-lasting of land, water and vegetation aimed at preventing, eliminating or reducing the habitat of vectors without causing an unduly adverse effect on the quality of the human environment.

**Environmental protection act**

The act relates to the protection and improvement of the human environment and the prevention of hazards to human beings, other living creatures, plants and property. The Act is an “umbrella” legislation designed to provide a framework for central government coordination of the activities of various central and state authorities established under previous laws, such as the Water Act and the air Act.

**Enzootic cycle**

The sylvatic cycle is the fraction of the pathogen population's lifespan spent cycling between wild animals and vectors. Pathogens that contain a sylvatic cycle include trichinosis, dengue viruses, *Yersinia pestis*.

**Enzyme**

Enzymes are biological catalysts (also known as biocatalysts) that speed up biochemical reactions in living organisms, and which can be extracted from cells and then used to catalyze a wide range of commercially important processes.

**Epidemic**

The occurrence of more cases of disease than expected in a given area or population during a particular period.

**Epidemiology**

Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations and the application of this study to the control of health problems.

**Epithelium**

Epithelium represents an interface between the internal and the external environment.

**Epizootic**

Disease events in an animal population are analogous to an epidemic in humans. An epizootic may be restricted to a specific locale (an "outbreak"), general (an "epizootic"), or widespread ("panzootic").

**Epizootics**

An epidemic outbreak of the disease in an animal population, often with the implication that it may extend to humans.

**Eradication**

It is the permanent reduction to zero of the worldwide incidences of infection caused by a specific agent as a result of deliberate efforts.

**Esterification**

Esterification is the general name for a chemical reaction in which two reactants (typically an alcohol and an acid) form an ester as the reaction product.

**Evaluation**

Evaluation is a systematic determination of a subject's merit, worth and significance,

using criteria governed by a set of standards. It can assist an organization, programme, design, project or any other intervention or initiative to assess any aim, realizable concept/proposal, or any alternative, to help in decision-making.

**Evaporation**

Evaporation can be defined as the process where a liquid is transformed into its gaseous state.

**Excavation**

Excavation means loosening and takeout materials leaving space above or below ground.

**Exophagic**

Insects, such as some mosquitoes, feed outdoors.

**Exophilic**

Insects, such as some mosquitoes, tend to inhabit or rest outdoors.

**Exotic fish**

A number of fish species have been imported from foreign countries and introduced for culture. Since these fishes are not the natives, they are called exotic fishes.

**Exotic species**

Exotic species often referred to as alien, non-native, non-indigenous, or introduced species, are those that occur in areas outside of their natural geographic range.

**Extraction**

Extraction is a process in which one or more components are separated selectively from a liquid or solid mixture.

**Extrinsic incubation period**

The interval between the acquisition of an infectious agent by a vector and the vector's ability to transmit the agent to other susceptible vertebrate hosts. E.g., in malaria - the extrinsic incubation period is 10-20 days.

**Fauna**

The aggregate of animal species inhabiting a particular region. The fauna of a region evolves historically from various animal groups known as faunistic complexes.

**Fecundity**

Fecundity is the physiological maximum potential reproductive output of an individual (usually female) over its lifetime and represents one of the major cornerstones of theoretical and applied population biology.

**Fertility**

Fertility is the natural capability to produce offspring. As a measure, the fertility rate is the number of offspring born per mating pair, individually or population-wise.

**Fertilizer**

A chemical or natural substance is added to soil or land to increase its fertility.

**Flooding irrigation**

Surface or flood irrigation is the application of water by gravity flow directly onto the soil. Flood irrigation is the oldest irrigation method, and in its uncontrolled form is a natural phenomenon on which many areas still base their crop cycle.

**Fogging**

Fogging is defined as space spraying of insecticide against mosquitoes to prevent an outbreak of mosquito-borne infection.

**Food chain**

The sequence of transfers of matter and energy in the form of food from organism to organism.

**Forest ecosystems**

A forest ecosystem is a community formed by plants and animals of that particular area that interact with the chemical and physical features of the environment in which they live.

**Formulation**

Putting together the components in appropriate relationships or structures according to a specific given formula. It is often used in a way that includes dosage in dispersible form.

**Gametocytes**

A gametocyte is a eukaryotic germ cell that divides by mitosis into other gametocytes or by meiosis into gametes during gametogenesis. The sexual stage of the malarial parasite in the blood may produce gametes when taken into the mosquito host; it may be male (microgametocyte) or female (macrogametocyte).

**Gastrointestinal**

Related to the stomach and intestine.

**Genal comb**

The genal comb is a row below the head, which is horizontally placed and is present in the back of the pronotum of a flea.

**Gene coding**

A mapping between tri-nucleotide sequences called codons and amino acids; every triplet of nucleotides in a nucleic acid sequence specifies a single amino acid.

**Gene expression**

Gene expression is the process by which the genetic code, the nucleotide sequence, of a gene is used to direct protein synthesis and produce the structures of the cell.

**Genes**

A gene is the basic physical and functional unit of heredity.

**Genetic modifications**

Genetically Modified Organisms (GMOs) can be defined as organisms in which the genetic material (DNA) has been altered in a way that it does not occur naturally by mating or natural recombination.

**Genitalia**

It's one of the reproductive organs of both sexes of insects.

**Genome**

A genome is an organism's complete set of DNA, including all of its genes. Each genome contains all of the information needed to build and maintain that organism.

**Genotypes**

Genotype is the complete gene set of the organism.

**GIS**

A Geographic Information System (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data.

**Globalization**

The term broadly refers to the expansion of global linkages, the organization of social life on a global scale. Globalization is a multifaceted phenomenon, which encompasses economic, social, political, technological and cultural dimensions.

**Granules**

Granules are agglomerates of powdered materials prepared into larger, free-flowing particles. They typically fall within the range of 850 µm to 4.75 mm in size. The shape of granules is generally irregular.

**Gravity**

Any two objects that have mass attraction towards each other with a force, we call gravity.

**Habitat**

Usually means the physical environment in which an animal lives, e.g., the skin in the case of scabies mites, streams for simuliidae larvae and animal nests for many ixodid ticks.

**Hazardous pesticides**

Hazardous Pesticides means pesticides that are acknowledged to consist particularly

high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as WHO or Global Harmonized System (GHS) or their listing in relevant binding international agreements or conventions.

**HBI**

The Human Blood Index (HBI) represents the proportion of blood meals derived from humans by mosquito vectors. It may be used to estimate the human biting habit, an important component of vectorial capacity, as a proxy measure of malaria transmission.

**Health hazard chemicals**

Health hazard chemicals means chemicals for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees.

**Homeostasis**

Homeostasis is the body's automatic tendency to maintain a relatively constant internal environment in terms of temperature, cardiac output, ion concentrations, blood pH, hydration, dissolved $CO_2$ concentration in blood, blood glucose concentration, concentrations of wastes, etc.

**Homologous chromosome**

Homologous chromosomes are made up of chromosome pairs of approximately the same length, centromere position, and staining pattern, for genes with the same corresponding loci. One homologous chromosome is inherited from the organism's mother; the other is inherited from the organism's father.

**Host**

An organism infected with or is fed upon by a parasitic or pathogenic organism (e.g., nematodes, fungi, viruses etc.). It is also described as an animal or plant that nourishes or supports a parasite.

**Hotspot**

It refers to areas of elevated disease burden or high transmission efficiency. Hotspot can also refer to an area with a high risk for infectious disease emergence or reemergence.

**Humidity**

The amount of moisture or water vapor present in the air. The absolute humidity changes as air temperature or pressure changes, if the volume is not fixed. The term "humidity" is a general term to quantify the amount of water vapor in the gas.

**Hybrid sterility**

Hybrid sterility is defined as the inhibition and suppression of the reproductive capacity of F1 or later-generation hybrids between genetically different strains or populations usually belonging to different species.

**Hydraulic**

It is denoting or relates to a liquid moving in a confined space under pressure.

**Hypnozoites**

Hypnozoites are dormant forms in the life cycles of certain parasitic protozoa that belong to the phylum Apicomplexa and are best known for their probable association with latency and relapse in human malarial infections caused by *Plasmodium ovale* and *P. vivax.*

**Hypostome**

The central unpaired holdfast organ of the tick capitulum; the hypostome is covered with recurved spines that enable it to serve as an anchoring device while the tick feeds.

**Immigration**

It is the number of individuals of the same species that have come into the habitat

from elsewhere during the period under consideration.

**Immunity**

The term 'immunity' is defined as resistance exhibited by the host against any foreign antigen including microorganisms. This resistance plays a major role in the prevention of infectious diseases. Immunity may be innate or acquired.

**Immuno-suppressed**

Immuno-suppression involves an act that reduces the activation or efficacy of the immune system. Some portions of the immune system itself have immuno-suppressive effects on other parts of the immune system, and immune-suppression may occur as an adverse reaction to the treatment of other conditions.

**Impoundments**

Impoundments are a common characteristic of human-dominated rivers and offer a means by which water travel time could be managed to promote denitrification.

**Incidence**

It is defined as the number of new cases occurring in a defined population during a specified period of time.

**Incubation period**

The time interval between invasion by an infectious agent and appearance of the first signs or symptoms of the disease.

**Indicators**

A quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect the changes connected to an intervention.

**Indoor Residual Spray**

IRS involves coating the walls and other surfaces of a house with a residual insecticide. For several months, the insecticide kills mosquitoes and other insects that come in contact with these surfaces.

**Infection**

It means the entry and development or multiplication of a pathogenic agent in the body of humans or animals.

**Infectivity rate**

It is typically used to measure the frequency at which disease spreads within a defined population during a specified time frame.

**Infestation**

It means the external invasion or colonization of animals or their immediate surroundings by arthropods, which may cause clinical signs or are potential vectors of pathogenic agents.

**Ingredients**

An ingredient is a substance that forms part of a mixture.

**Insect Growth Regulators (IGRs)**

Sometimes known as insect development inhibitors. IGRs are a group of chemicals that either prevent the development of larvae into pupae or pupae into an adult.

**Insecticide**

Insecticides are toxic substance that is used to kill insects. Such substances are used primarily to control pests that infest cultivated plants or to eliminate disease-carrying insects in specific areas.

**Insecticide resistance**

The ability of arthropods to tolerate doses of insecticides, which would prove lethal to the majority of normal (susceptible) individuals of the same species.

**Insecticide-Treated Nets**

Insecticide-Treated Nets (ITNs) are a form of personal protection, which are simple mosquito nets that have been treated with an insecticide. These nets require ‘re-dipping' to restore the insecticide element every 6-12 months.

**Integrated Pest Management**

Integrated Pest Management **(**IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties.

**Integrated Vector Management**

Integrate Vector Management (IVM) is a rational decision-making process for the optimal use of resources for vector control. The approach seeks to improve the efficacy, cost-effectiveness, ecological soundness and sustainability of disease-vector control. The ultimate goal is to prevent the transmission of vector-borne diseases such as malaria, dengue, Japanese encephalitis etc.

**Intensity**

Intensity refers to the rate at which the activity is being performed or the magnitude of the effort required to perform an activity or exercise.

**Intermediate host**

Ordinarily, a necessary host and one in which only the immature stages occur in the host, for example- The human body is an intermediate host for Plasmodium parasite.

**Invertebrates**

Invertebrates belong to the animal kingdom. They lack a backbone and have soft bodies because they don't have an internal skeleton (endoskeleton) for support although, some of them possess an exoskeleton that encompasses the entire body. Invertebrates do not possess lungs since they respire through their skin and are heterotrophic.

**Irrigation**

The process of supplying water to land by artificial means. Its basic objective is to supplement the natural supply of water, for raising crops with an economic and efficient system. Controlling and harnessing various natural resources. To achieve it, irrigation systems are required.

**Isomers**

If two or more different compounds have the same molecular formula, they are known as isomers.

**Labium**

A lower mouthpart of an insect that is formed by the second pair of maxillae united in the middle line formed by a fusion in embryonic life of separate right and left maxilla.

**Labrum**

An upper or anterior mouthpart of an arthropod consists of a single median piece, which forms the floor of the mouth in mandibulate insects with many sensory structures.

**Landfills**

The landfill is defined as a "facility in which solid waste from municipal and/or industrial sources is disposed of in the land.

**Larval density**

Larval density is the number of larvae collected to the number of dips made.

**Larval habitat**

These are the places where eggs are laid, larvae hatch, instars moult, pupate, and adults emerge. They may be natural or man-made, permanent or temporary, large or small.

**Larvicide**

A larvicide is an insecticide that specifically targets the larval life stage of an insect. Larvicides may be contact poisons, stomach poisons, growth regulators, or (increasingly) biological control agents and are most commonly used against mosquitoes.

**Lethal mutation**

A type of mutation in which the effect(s) can result in death or reduce significantly the expected longevity of an organism carrying the mutation.

**Light trap**

Light trapping is the most common and regular sampling technique. Nocturnal arthropods particularly insects are attracted by artificial light sources therefore light traps have been widely used to collect nocturnal insects.

**LLINs**

LLIN is a mosquito net impregnated with insecticide. The insecticide is cleverly bounded within the fibres that make up the netting and is 'slow released' over a 4-5 years period.

**Longevity**

How long an organism lives, is often expressed as the mean expectancy of life. Vector longevity is one of the most important factors in disease transmission dynamics and vector control.

**Lymph node**

The lymph nodes are organized lymphoid organs that contain lymphocytes within a fine reticular stroma.

**Lymphatic system**

The lymphatic system is part of the vascular system and an important part of the immune system, comprising a large network of lymphatic vessels that carry a clear fluid called lymph directionally towards the heart.

**Mammalian toxicology**

Mammalian Toxicology surveys chemical agents and examines how such chemicals impact Mammalian health, emphasizing the importance of minimizing environmental exposure to chemical and physical hazards through media like contaminated water, soil and air.

**Mammals**

Mammals are various warm-blooded vertebrate animals of the class mammalian, including humans, characterized by a covering of hair on the skin and, the presence of milk-producing mammary glands in females for nourishing the young.

**Man Hour Density**

Man Hour Density (MHD) is an important index to determine relative densities of mosquitoes to compare the prevalence of vectors in the same areas of seasons, months or years or to compare different places also.

**Management**

Management is the organizational process that includes strategic planning, setting objectives, managing resources, deploying the human and financial assets needed to achieve objectives, and measuring results.

**Mandible**

The jaws present in biting and chewing insects. Mandibles can be needlelike piercing organs, present in mosquitoes, or tooth-like present in chewing lice.

**Maxilla**

The second pair of jaws in chewing insects is persistent when the mouth is modified.

**MDA**

Mass Drug Administration (MDA) is the administration of anti-malarial treatment to every member of a defined population or every person living in a defined geographical area at approximately the same time and often at repeated intervals.

**Mechanical control method**

Mechanical control methods involve the complete or partial removal of plants by mechanical means, including harvesting, shredding, mowing, rototilling, rotovating and chaining.

**Meral rod**

A vertical thickening of the body wall (mesopleuron part) of the thorax of fleas.

**Merozoite**

Daughter cell resulting from schizogony (merogony).

**Metamorphosis**

The relatively abrupt change in body form between the immature and sexually mature adult stages.

**Microcephaly**

Microcephaly is a birth defect where a baby's head is smaller than expected when compared to babies of the same sex and age.

**Microfilaria**

First-stage juvenile filaria nematodes are usually found in the blood or tissue fluids of the definitive host.

**Mists**

Mists are dispersions of liquids in gases. They are formed during the nebulization of liquids, during condensation from the vapour phase and during chemical processes (for example oil mist, and hydrogen chloride in damp air).

**Monocytes**

Monocytes are a type of white blood cell that fights off pathogens. Monocytes are the biggest type of white blood cell in the immune system. Firstly, they are formed in the bone marrow, which is released into our blood and tissues. When certain germs enter the body, they quickly rush to the site for attack.

**Morphology**

Morphology is the study of the shapes and arrangement of parts of organisms, in order to determine their function, their development, and how they may have been shaped by evolution.

**Mortality**

A mortality rate is a measure of the frequency of occurrence of death in a defined population during a specified interval.

**Mortality rate**

A mortality rate is a measure of the frequency of occurrence of death in a defined population during a specified interval.

**Moulting**

Moulting is the process of producing a new cuticle and the subsequent shedding of the old cuticle.

**Mutagenesis**

Mutagenesis refers to those changes in the genetic material in cells brought about spontaneously either by chemical or physical means whereby successive generations differ in a permanent and heritable way from their predecessors.

**Mutation**

A mutation is a heritable change in the genetic material that is not due to genetic recombination. The mutation alters the structure or number of genes or entire chromosomes.

**Neglected tropical disease**

The diverse group of communicable diseases that prevail in tropical and subtropical regions countries e.g., malaria, chikungunya, dengue, lymphatic filariasis.

**Nematodes**

A member of phylum Nematoda comprising elongated cylindrical worms, parasitic in animals or plants or free-living in soil or water.

**Neurotoxicity**

Neurotoxicity refers to the direct or indirect effect of chemicals that disrupt the nervous system of humans or animals. Numerous chemicals can produce neurotoxic diseases in humans, and many more are used as experimental tools to

disturb or damage the nervous system of animals.

**N-methyl Carbamates**

Methyl carbamate (also called methylurethane, or urethylane) is an organic compound and the simplest ester of carbamic acid ($CH_3NO_2$).

**Nocturnal**

Some organisms are active during the night therefore they are called as nocturnal. e.g., microfilariae of *Wuchereria bancrofti* nocturnally periodic.

**Non-target biota**

Non-target organisms/ species are not the direct targets for their control or management.

**Nozzles**

A nozzle is a simple device used to break apart a fluid flow into a spray pattern. It atomizes liquid into droplets, disperses the droplets in a specific pattern, metres liquid at a certain flow rate and provides hydraulic momentum.

**Nymph**

Nymphs are the immature form of an insect, such as an apterygote arthropod, which does not pass through a pupal stage during metamorphosis. Nymphs resemble adults' stages but are smaller and lack fully developed wings and genitalia.

**Oil in water emulsion**

Oil-in-water emulsions are conventionally defined as thermodynamically unstable systems, which include two immiscible liquids (generally water and oil), in which oil is distributed into the water.

**Omnivorous**

Omnivores consume materials from different trophic levels of the food web. Many, if not most, aquatic animals eat more than one type of food during their lifespan, both from the plant as well as animal origin.

**Organization**

A social unit of people, systematically structured and managed to meet a need or to pursue collective goals continuingly.

**Outbreak**

Outbreak is an occurrence of significantly more cases of disease than expected in a given area among a specific group of people over a particular period of time.

**Palmate hair**

Palmate hair is the hair of seta with flattened, movable, usually horizontal branches radiating from a common point on a short stem.

**Parasite**

A parasite is a microorganism which lives on a living host and derives nutrition from the host, without any benefit to the host.

**Parasitemia**

The presence of parasites in the blood.

**Passive Surveillance**

Regular reporting of disease data by all institutions that see patients (or test specimens) and are part of a reporting network is called passive surveillance.

**Pathogens**

A pathogen is defined as an organism causing the disease to its host. Pathogens are taxonomically widely diverse and comprise viruses and bacteria as well as unicellular and multicellular eukaryotes.

**Pathogenesis**

The parasite or pathogen can interfere with one or more of the essential functions of the plant or animal.

**Persistent Organic Pollutants**

Persistent Organic Pollutants (POPs) are chemicals of global concern due to their potential for long-range transport, persistence in the environment, ability to bio-magnify and bioaccumulation in ecosystems, as well as their significant

negative effects on human health and the environment.

**Pesticide**

Pesticides are chemical compounds that are used to kill pests e.g., DDT, Malathion, Pyrethrum etc.

**Pests**

Pest is an insect (or organism) that causes harm to humans, their livestock, crops or possessions. Pest includes nematodes, weeds, bacteria, insects, fungi, molluscs, phytoplasma, viruses and viroids.

**Pesticides**

Pesticides are chemical compounds that are used to kill pests.

**Phagocytes**

A cell that can engulf particles, such as bacteria and other microorganisms or foreign matter. Principal phagocytes include neutrophils and monocytes, both of which are types of white blood cells.

**Phytochemicals**

Phytochemicals are defined as bioactive nutrient plant chemicals in fruits, vegetables, grains, and other plant foods that may provide desirable health benefits beyond basic nutrition to reduce the risk of major chronic diseases.

**Pleural rod**

Pleural rod is a vertical ridge that divides the mesosternum (thoracic plate above the coxa of the 2$^{nd}$pair of legs).

**Pneumonia**

Pneumonia is "a severe form of an acute lower respiratory infection that specifically affects the lungs" and is typically caused by bacteria.

**Pneumonic plague**

Infection of the lungs by Yersina pestis, the bacterial agent that causes plague (a human disease).

**Polarity**

In chemistry, polarity refers to the way in which atoms bond with each other.

**Population density**

Population density is defined as the number of persons per square kilometre. It is an important index of population, which shows the concentration of the population in a particular area.

**Predator**

An animal that feeds upon other animals (prey) that are either smaller or weaker than itself.

**Prevalence**

Prevalence measures the amount of disease in a population at a given time and can be expressed as a percentage. The point prevalence is a single assessment at a fixed point in time, whereas the period prevalence is the percentage of a population who has the disease at any time within a stated period.

**Proboscis**

In invertebrates, the term usually refers to tubular mouthparts used for feeding and sucking. The proboscis is used to describe an elongated nose or snout.

**Progeny**

The product of reproduction or replication, also known as offspring.

**Proliferation**

To proliferate normally means to increase rapidly in number or quantity, or to grow or reproduce by rapid production of new parts (biological).

**Promastigotes**

A stage in the unicellular life-cycle, typically trypanosomes, where the flagellum is anterior to the nucleus and free from the cell body.

**Pronotal comb**

The pronotal comb is a row behind the head, at the back of the pronotum.

**Prothorax**

The first thoracic segment bears the anterior legs but no wings.

**Protonymph**

It is the first instar of the growth and developmental stage in mites.

**Protozoa**

Protozoa are single-celled, animal-like organisms.

**Protozoan**

Single-celled animals with at least one well-defined nucleus, some of which are pathogenic.

**Public health**

Public health is the science of protecting and improving the health of people and communities.

**Public health entomology**

Public health entomology focuses on the population biology of vector-borne infections, seeking to understand how such pathogens perpetuate over time and attempting to devise methods for reducing the burden that they impose on human health.

**Pulvilli**

The expanded terminal structure of the pretarsus of some genera of mites, which may be membranous bell- or sucker-like discs.

**Radiation**

Energy moving in the form of particles or waves. Familiar radiations are heat, light, radio, and microwaves.

**Recrystallization**

The process of recrystallization involves the dissolution of the solid in an appropriate solvent at an elevated temperature and the subsequent re-formation of the crystals upon cooling so that any impurities remain in the solution.

**Remote sensing**

Remote sensing is science of obtaining information about an object or feature without physically coming in contact with that object or feature. The process infers surface parameters from measurements of electromagnetic radiation (EMR) from the earth's surface. This EMR can either be reflected or emitted from the Earth's surface. It is a useful tool for vectorborne diseases.

**Repellents**

Substances applied to skin, clothing, or other surfaces, which discourages insects (particularly mosquitoes) to sit, climb or bite. Repellents are used to repel mosquitoes, ticks, flies, and other biting insects.

**Reservoir**

Reservoirs are those water bodies formed or modified by human activity for specific purposes, in order to provide a reliable and controllable resource.

**Resistance**

A genetic change in an organism in response to selection by drugs/pesticides, which may impair control in the field.

**Sanitation**

Sanitation refers to the provision of facilities and services for the safe management of human excreta from the toilet to containment and storage and treatment onsite or conveyance, treatment and eventual safe end use or disposal.

**Schizonts**

Mature malaria parasite in host liver cells (hepatic schizont) or red blood cells (erythrocytic schizont) that is undergoing nuclear division by a process called schizogony.

**Scutum**

The sclerotized plate on the dorsal surface of Ixodidae hard ticks, also known as the dorsal shield.

**Serotype**

A group within a single species of microorganisms such as bacteria or viruses share distinctive surface structures.

**Slide *falciparum* Rate (S*f*R)**

Percentage of slides found positive for P. falciparum parasite from examined slides.

**Slide Positivity Rate (SPR)**

Percentage of slides found positive for malaria parasite from examined slides.

**Social mobilization**

Social mobilization is the process of bringing together all societal and personal influences to raise awareness of and demand for health care, assist in the delivery of resources and services, and cultivate sustainable individual and community involvement.

**Space spraying**

A space spray – technically a fog (sometimes referred to as an aerosol) – is a liquid insecticide dispersed into the air in the form of hundreds of millions of tiny droplets less than 50 µm in diameter. It is only effective while the droplets remain airborne.

**Species**

A group of individuals in natural populations that can inter-breed by mating within the group and producing fertile progeny; individuals are usually similar in appearance and behavior.

**Spermatheca**

The spermatheca is a single pouch-like structure connected by the median oviduct through spermathecal duct, which receives spermatophore during copulation. In higher diptera, there is three spermatheca present.

**Spinosad**

Spinosad is a naturally derived fermentation product, which has demonstrated insect control activity against a large number of pests. The product is isolated from actinomycetes *Saccharopolyspora spinosa*.

**Spiracles**

A breathing pore is an external aperture and is sometimes guarded by the valves from which the oxygen is inhaled and carbon dioxide is exhaled into the environment. The number of spiracles may vary from species to species and in generalized insects 2 thoracic and 8 abdominal spiracles are present.

**Spiracular bristles**

It is a stiff hair-like structure of any of several tracheal openings in the exoskeleton of an insect, spider, or another terrestrial arthropod.

**Sporogony**

The sexual stage in the life cycle of a sporozoan parasite, with the development of the zygote into one or several haploid spores, each containing a distinctive number of sporozoites.

**Sporozoite rate**

Sporozoite rate is the number of mosquitoes infected with sporozoites divided by the total number of mosquitoes examined using each respective method of mosquito collection, expressed as a percentage.

**Sporozoites**

It refers to the minute, motile, an infective form of certain protozoa, which infects the host cells. For example, sporozoites of *plasmodium* are the infective protozoans, injected by the mosquito.

**Sterilization**

Sterilization describes a process that destroys or eliminates all forms of microbial life and is carried out in healthcare facilities by physical or chemical methods.

**Stylostome**

The feeding tube produces around the mouth parts of trombiculid mites in the skin of the host.

**Surveillance**

Systematic ongoing collection, collation, and analysis of data and the timely dissemination of information to those who need to know so that action can be taken.

**Susceptibility**

Susceptibility means "the state of being susceptible" or "easily affected."

**Tarsi**

It is the jointed appendages attached at the apex of the tibia and bears the claws and pulvilli.

**Temephos**

Temephos is a non-systemic organophosphorus insecticide, mainly used as a larvicide to control mosquitoes.

**Thermal fogging**

Thermal fogging is the generation of ultra-fine droplets in a range of 1-50 µm using thermo- pneumatic energy. The fluid to be fogged is first vaporized by an increase in temperature and the vapour is then condensed upon introduction to the cooler atmospheric air.

**Thorax**

The thorax or chest is a part of the anatomy of various animals located between the neck and the abdomen. The thorax includes the thoracic cavity and the thoracic wall.

**Toxicity**

Toxicity can be defined as the relative ability of a substance to cause adverse effects in living organisms.

**Transgenic strain**

Organisms into which genetic material from another organism has been experimentally transferred.

**Transmission intensity**

The frequency with which people living in an area are bitten by anopheline mosquitoes carrying human malaria sporozoites

**Transovarial transmission**

The transmission of an infectious agent from parent to offspring via infection of the developing egg, which subsequently results in infectious adult arthropods is an important transmission mechanism among viruses in the order Bunyavirales.

**Transstadial transmission**

It occurs when a pathogen remains with the vector from one life stage to the next.

**Trophozoites**

It is the general term for the active, feeding, and multiplying stages of most protozoa. In parasitic species, this is the stage usually associated with pathogenesis.

**Tropical countries**

Tropical countries are those that lie within the region that lies between the tropic of cancer and the tropic of Capricorn. India is therefore a tropical country.

**Urbanization**

Urbanization is an index of transformation from traditional rural economies to modern industrial ones. It is a progressive concentration of the population in urban units.

**Vaccine**

Vaccines are biological agents that elicit an immune response to a specific antigen derived from an infectious disease-causing pathogen, that enhance immunity against disease and either prevents (prophylactic vaccines) or, in some cases, treats disease (therapeutic vaccines).

**Vector**

Vector is described as an arthropod or any living carrier that transports an infectious agent to a susceptible individual. Transmission by a vector may be

mechanical or biological e.g., mosquito, bed bugs, ticks, mites, fleas etc.

**Vector Borne Diseases (VBDs)**

Infectious diseases of animals and humans caused by pathogenic agents such as bacteria, helminths, protozoa and viruses transmitted by hematophagous arthropod vectors, which include bedbugs, biting midges, black flies, fleas, kissing bugs, lice, mites, mosquitoes, sand flies and ticks, among others.

**Vector density**

The prevalence of vectors in a particular area is termed as vector density.

**Vector incrimination**

The vector capable to transmit the pathogen to an uninfected host is called vector incrimination.

**Vectorial capacity**

It is a measurement of the efficiency of vector-borne disease transmission.

**Vegetation**

Vegetation can be defined as an assemblage of plants of one-to-many species growing in areas of different sizes.

**Vegetation manipulation**

Vegetation manipulation refers to any human interference with the normal processes in the plant's life in order to stimulate or retard growth, to change its shape or growth model, or to stimulate or retard flowering and fruit set by applying physical or chemical procedures.

**Vertebrates**

Vertebrates are members of the larger phylum chordata. The distinct feature is presence of the vertebral column, or backbone, which surrounds and protects the main nerve cord. Other major chordate features at some point in their life cycles includes notochord, dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail.

**Vertebrate Animals**

An animal with a skull, which surrounds the brain and a skeleton of bone or cartilage, including the spine of vertebral bones surrounding a spinal cord of nerves; includes mammals, aves, fishes, reptiles and amphibians.

**Vertical transmission**

Transmission of an infection from a mother to her offspring during the perinatal period (the period immediately before and after birth). Transmission might occur across the placenta, in the breast milk, or through direct contact during or after birth. eg., HIV, hepatitis B and hepatitis C.

**Veterinary**

Relating to the diseases, injuries, and treatment of farm and domestic animals.

**Vicinity**

The area or region near or about a place; surrounding district; neighbourhood.

**Virology**

Virology is the study of viruses, complexes of nucleic acids and proteins that have the capacity for replication in animal, plant and bacterial cells.

**Virulence factors**

It determines the degree to which the pathogen causes damage, invasion, and infectivity.

**Volume Median Diameter (VMD)**

The volume median diameter is the diameter half the volume of the aerosol particles contained in particles with larger diameters and half is contained in particles with a smaller diameter.

**Waterholes**

Wildlife water holes are an important habitat component for a variety of wildlife. They provide drinking water for many wild animal species including bats, wild boars, elephants turkeys and deers and

these also serve as breeding habitat for many amphibians.

**Wetlands**

Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.

**Wettable powder**

Water dispersible powder technical grade insecticide diluted with an inert carrier (dust) and to which a wetting agent or surfactant has been added. The resultant wettable powder is then mixed with water for spraying onto the surface.

**Zoonotic disease**

A disease that can be transmitted from animals to people or, more specifically, a disease that normally exists in animals but that can infect humans. There are multitudes of zoonotic diseases.

**Zoophagic**

Zoophagic is defined as feeding on animals or animal matter; specifically (of a mosquito) feeding on animals other than humans.

**Zoophilic**

Zoophilic mosquitoes are mosquitoes that prefer animals for blood.

**Zygote**

Cell that forms by the union of a male and female gametes.

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