Indira Gandhi
National Open University
School of Sciences

BZYET-143
INSECT VECTORS AND VECTOR BORNE DISEASES

Block

4

MEDICALLY IMPORTANT INSECT VECTORS-III AND IVM

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BLOCK 4: MEDICALLY IMPORTANT INSECT VECTORS-III AND IVM

Mosquito vectors, mosquito borne diseases and their control was explained in detail in Block 3. In Block 4, you will study about houseflies, sandflies, diseases caused by them and their control. The block consists of three units. Unit 13 speaks about houseflies and Filth flies which belong to the *Musca* genus and can be important mechanical vectors of diarrhoeal diseases (most commonly the 'house fly' *Musca domestica*) and eye diseases (most commonly *Musca sorbens*).

- Filth files breed in organic matter: garbage (*M. domestica*) and human faeces (*M. sorbens*) and
- Feed on food and organic matter (*M. domestica*) eye and wound secretions (*M. sorbens*).

Flies occur wherever there is suitable breeding material, and the temperature and humidity are suitable for development. Flies transmit a number of different diseases mechanically but are never the sole transmission route (multiple transmission routes are the norm). Diarrhoeal diseases, (such as shigella, salmonella, and cholera) are transmitted by houseflies (especially *M. domestica*). Flies which are attracted to the secretions around the eyes and to wounds (usually *M. sorbens*) may be particularly important in transmitting trachoma, a chronic disease of the eye that can lead to visual impairment, even blindness. Control programmes for flies should, wherever possible, be based on providing suitable and effective methods of sanitation and garbage disposal. Insecticide control of flies is recommended when an epidemic of cholera, dysentery, or trachoma is threatened or underway.

Unit 14 tells about another important disease vector i.e. sandflies (*Phlebotomus species*). The adults of sandfly are small, fuzzy with delicately proportioned body, 1/4 the size of mosquito. These are natives of warm climate. Leishmaniasis is a disease of humans and dogs infected with *Leishmania* parasites. There are three principal forms of the disease: cutaneous (e.g. *L. tropica,* usually self-healing); visceral (*L. donovani,* usually fatal if not treated); and mucocutaneous (*L. brasiliensis,* outcome variable). Different species of sandflies (*Phlebotomus* and *Lutzomyia* spp) are vectors of leishmaniasis, and also sandfly viral fever. Termite mounds have long been associated with certain leishmaniasis vector species in east Africa (e.g. *P. martini* in Kenya) but their importance for *P. orientalis* is not clear.

Unit 15 discusses about integrated vector management (IVM), its concept and application in the field. IVM is a rational decision making process to optimize the use of resources for vector control. It is vital in successfully combating vector borne diseases. The prevention and control of malaria, dengue, JE and leishmaniasis are linked closely to various ecological factors. Source reduction, mechanical chemical, biological, genetic, hormononal and legislative control are important components of IVM. There are various approaches for its implementation.

Objectives

After studying this block you will be able to:

- list distinguishing characters of sandfly, *Phlebotomus argentipes*,
- discuss the life cycle of *Phlebotomus argentipes*,

- explain the transmission of kala-azar by *Phlebotomus argentipes*,
- recognize other diseases spread by Phlebotomines,
- describe the status of kala-azar in the country,
- explain the control measures adopted for sand fly and kala-azar elimination,
- explain the characteristic features and biology of housefly,
- detail and draw the life cycle of housefly,
- explain the behavior of housefly,
- discuss the role of houseflies as vector of diseases,
- describe the preventive and control measures of houseflies,
- define Integrated Vector Management (IVM),
- list the elements of IVM,
- explain different types of vector control methods, and
- describe the activities of different sectors for IVM.

You are advised to go through the Annexures nd Appendix given at the end of the Block and the Volume. They provide comprehensive overview of the Units.

UNIT 13

DIPTERANS AS DISEASE VECTORS-IV (SAND FLIES)

Structure

13.1 INTRODUCTION

In this unit you will study about another dipteran group transmitting disease, commonly known as Kala-azar (KA) or Visceral Leishmaniasis (VL) and Oriental sores or Cutaneous Leishmaniasis (CL).

These vectors, commonly called as sand flies are grouped under family Psychodidae and two subfamilies, namely Psychodinae and Phlebotominae which transmit different type of leishmaniasis. The subfamily Phlebotominae comprises six genera namely *Phlebotomus*, *Segentomyia*, *Brumptomyia*, *Lutzomyia*, *Warileya*, and *Parvideus*. Of these, only two genera named *Phlebotomus, Segentomyia* are found in the Indian subcontinent and are represented by 46 species.

In India and other parts of the Old World, the VL is caused by the pathogen *Leishmania donovani*, and CL is caused by *Leishmania tropica* transmitted by the vector *Phlebotomus argentipes*. However, in the New World, the disease is transmitted by another genus *Lutzomyia.* Until now *Phlebotomus argentipes* is the only known vector of Kala-azar in India.

Objectives

After studying the unit, you should be able to:

- list distinguishing characters of sandfly, *Phlebotomus argentipes*,
- discuss the life cycle of *Phlebotomus argentipes*,
- explain the transmission of kala-azar by *Phlebotomus argentipes*,
- recognize other diseases spread by Phlebotomines,
- describe the status of kala-azar in the country, and
- explain the control measures adopted for sand fly and kala-azar elimination.

13.2 LIFE CYCLE OF SANDFLY

The life cycle of *P. argentipes* consists of 4 stages namely Egg, Larva, Pupa and adult (Fig. 13.1).

13.2.1 Adults

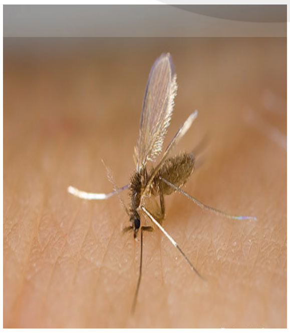

Fig. 13.1: Adult sand flies: *Phlebotomus papatasi* and *Phelobotomus argentipes*.

The adults of sand fly (*Phlebotomus*) are small, fuzzy, with delicately proportioned body, usually ¼ of the size of the mosquito. These are golden, brownish or grey-coloured with large black eyes. These are 1.5 to 3.5 mm long and possess a highly fragile body. The males and unfed females can pass through mosquito net easily. The body, wings, and legs are heavily clothed with long hairs. The wings and legs are larger than the size of body. The sand fly can be distinguished from other insects and spotted easily because of the posture of its wings which are held vertically erect on the abdomen, in V-shape, when at rest (Fig. 13.1).

Of the five psychodid subfamilies, only the sand flies (Phlebotominae) have piercing mouthparts capable of sucking blood. The females have rounded abdominal end while males have claspers attached to their last abdominal segment.

13.2.2 Eggs

Sand fly adult females lay single eggs in small batches of roughly 30-70 eggs. The freshly laid eggs are creamy-white in colour which later turn dark. The eggs are usually deposited in cracks and crevices with high organic content, humidity and darkness. Sometimes eggs are also found in loose soil (Fig. 13.2).

Fig. 13.2: Sand Fly's eggs.

The eggs are glued from the flattened surface while the convex side faces upwards. The egg shell has sculptors and their size varies from 0.336" - 0.432 mmx0.096-0.160 mm. The eggs are unable to stand desiccation and hatch in 3-4 days at 26$\pm$ 2C°.

13.2.3 Larvae

The larva is creamy-white with distinct head, thorax and abdomen provided with numerous hairs on its body. They are mainly scavengers and feed on organic matter available in the soil such as decaying vegetation, fungi, animal faeces etc. The life cycle comprises four larval stages.

i) **I instar:** The delicate larva is whitish with a brown head capsule lacking eyes. A pair of black caudal bristles and presence of egg breaker on the posterior portion of head are the characteristic features of I instar larva. Within 2-4 days it transforms to II instar larva.

ii) **II instar:** Second instar has 2 pairs of caudal bristles, round 3rd antennal segment and thick bristles on the head and all body segments. The egg breaker disappears. It lives for about 2-5 days and converts to next instar (Fig. 13.3).

iii) **III instar:** Presence of 2 caudal bristles on completely dark last abdominal segment, partially elongated 3rd antennal segment and yellowish body hairs help in identifying III instar which lasts for about 3-4 days.

iv) **IV instar:** It is 3-7 mm long brown larva with dark brown head capsule, elongated, and an oval 3rd antennal segment with a pointed seta. Two pairs of spiracles and two pairs of well-developed caudal bristles are conspicuous. The stage lasts for 4-7 days and then transforms into pupa.

The total larval period may vary from 11-29 days depending upon the temperature, moisture and availability of food.

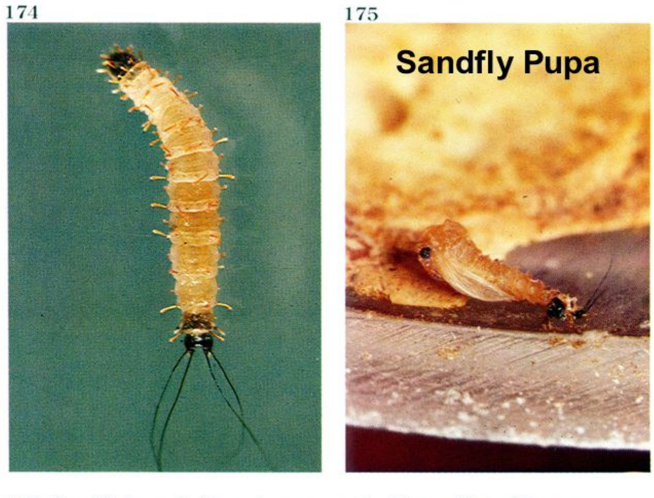

Fig. 13.3: Sand fly larva and Pupa.

13.2.4 Pupae

The pupa is elongated and comma-shaped. It is milky white in the beginning and turns brown gradually. During pupal emergence, the larval skin is not completely shed and remains attached to the end of pupal body. Presence of larval skin with two pairs of peculiar caudal bristles at the abdominal end makes the most characteristic feature of sand fly pupa and aids in its recognition.

The pupa is a non-feeding stage lasting for about 6-10 days. The sexes are differentiated in this stage.

The total life cycle of *Phebolomus argentipes*, from egg to adult, is about 20-36 days with an average of 26.75 days (Fig. 13.4).

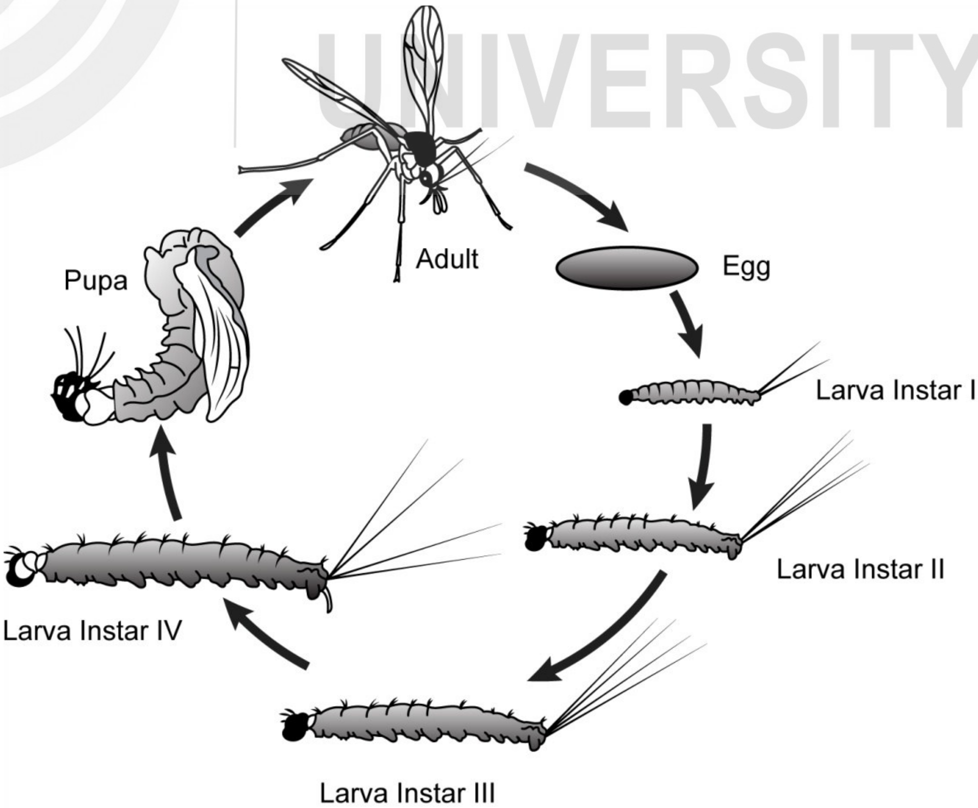

Fig. 13.4: Life cycle of sand fly.

13.3 BEHAVIOR

The sand flies are the natives of warm climate. They can be grouped into two categories based on climatic conditions, species associated with the wet zone and the species associated with the arid zone. The favourable conditions considered for sand fly breeding and feeding are; alluvial soil with high sub-soil water, monthly mean maximum temperature below 37C°,annual rainfall of ≥ 1250mm ,mean relative humidity of ≥ 70% and abundant vegetation. These factors favour *Phlebotomus argentipes*, the only known vector of visceral leishmaniases in India, to survive with high prevalence facilitating transmission.

13.3.1 Distribution and Habitat

P. argentipes is one of the widely distributed sand flies and is essentially the species of wet zone (Fig. 13.5). The species is predominantly distributed all along the eastern coast from West Bengal to Kanyakumari. Though, commonly not found at the altitude above 600 m, the sporadic occurrence of the sand flies has been recorded in Kasauli at an altitude of 1200 m and in Pauri Garhwal in the Himalayan region at 1300 m.

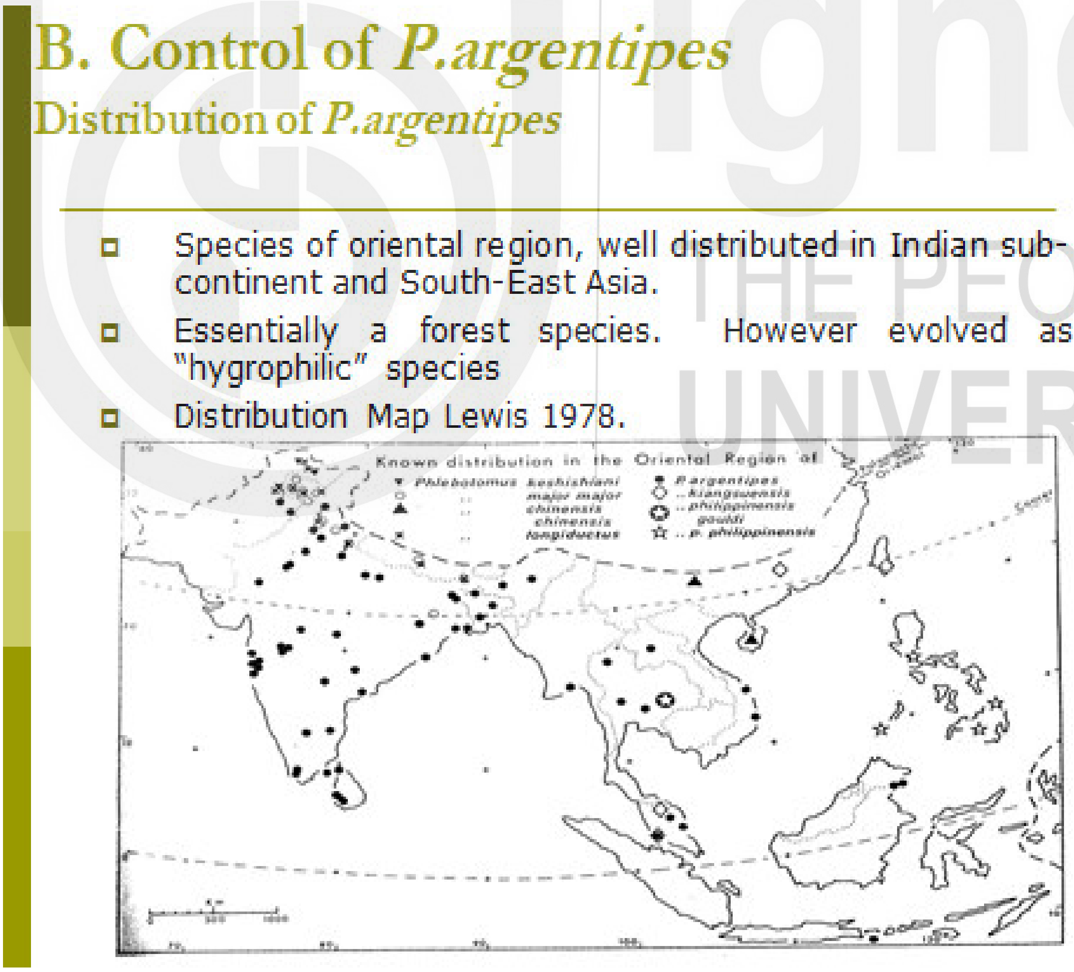

Fig. 13.5: Distribution of sand flies.

Phlebotomus species occur predominantly in warm, humid and tropical climates, usually in savannah and semi-desert vegetation habitats, although a few species are found in temperate zones. They require a humid microclimate for their eggs to develop while larvae need a cool, moist habitat with decaying debris. Adult sand flies often inhabit rock crevices, caves, and rodent burrows. They rest in cool, dark and humid corners of animal shelters or around human dwellings. Both rodent burrows and peri-domestic areas provide shelter as well as easy access to blood meals.

The species is found throughout the year in majority of prevalent areas with complete absence in winter months in areas with extremes of temperatures like Assam. With the onset of warm weather, the population density increases reaching the maximum during and just after the monsoon rain.

13.3.2 Reproduction and Oviposition

Adult sand flies mate soon after emergence. Males locate females at resting sites or on the vertebrate hosts, with the aid of pheromones. Female sand flies usually lay 30–70 eggs during a single gonadal cycle. These eggs are deposited in cracks and holes in the ground or in buildings, animal burrows and among tree roots. The eggs require a microhabitat with high humidity in order to survive, but are never laid in water. Generally, one blood meal results in the production of a single batch of eggs.

13.3.3 Dispersal

Adult sand flies are weak fliers, travelling with a characteristic short hopping flight, and usually do not disperse more than a few hundred metres from their breeding sites. Most species fly horizontally near ground level. In temperate and arid regions, sand flies may diapause (a period of physiologically enforced dormancy between periods of activity) as a mature larva and develop as soon as summers arise.

13.3.4 Feeding and Host Preference

All species of sand flies feed on sugary nutrients derived from the plant nectar and honey dew, while the females are sanguivorous (feed on blood). Host availability and blood feeding is an important factor for the vectorial capacity of sand flies. As discussed earlier, female sand flies feed on a wide variety of vertebrate hosts, including humans, livestock, dogs, urban and wild rodents, reptiles, amphibians and birds. Each species of sand fly may have its own specific host preferences. *Lutzomyia shannani* feeds on white-tailed deer, horses, donkeys, mules, cattle, swine, raccoons, rodents, birds and humans while *Phlebotomus* feed on only mammals.

Many species are opportunistic and feed on animals to which they have easiest access. The choice of host is also influenced by the proportion of each host. Thus, in urban and peri-urban settings, humans and domestic dogs are the main targets of sand files. According to a WHO report, *P. argentipes* which is commonly known as zoophilic, can show anthropophilic behavior depending on the availability of host in the sampling site. As per report, the samples collected from human habitation showed 69.6% anthropophilic index (or Human Blood Index is the proportion of recently fed mosquitoes, usually vector species that have taken a human blood meal) whereas the samples collected from cowshed in the same area show only 21.6% anthropophily. Thus, *P. argentipes* can be considered as indiscriminate (opportunistic) feeders and take blood meal of the host available in its immediate vicinity.

13.3.5 Flight Range

Sand flies cannot fly very long distances. Their usual mode of flight pattern is a series of short erratic hopping in which the fly usually covers a distance less than ½ meter. Further, dependence of the most of the vectors on humidity for their survival limits their movements.

13.3.6 Resting Sites

The most favoured resting sites for sand flies include soil cracks and crevices, burrows of rodents, tree holes, termite hills, caves, bird tunnel, earthen mounds, under stone and foliage, etc. In eastern parts of India like Bihar and West Bengal, *P. argentipes* prefers to rest indoors, about 9-10 times higher in cattle dwellings than the human dwellings. In western India, sand flies even rest outdoors in considerable numbers. All these resting places provide them dark and damp shelter where the microclimatic humidity is very high. They usually leave these shelters at dusk and are active in open in the evening and night. Usually sand flies remain active throughout the night but they are sensitive to decreasing temperature and air currents. Even a gentle breeze of 1.5-2 m/sec may greatly reduce their activity.

13.3.7 Longevity

P. argentipes are reported to undergo 5 gonotrophic cycles under laboratory conditions, duration of each cycle being 4 to 5 days at 26+ 2ºC *i.e.* a minimum longevity of up to 23- 27 days. Field studies conducted on parity have also shown the presence of triparous and four parous females in nature indicating probability of longevity under field conditions to be up to 16-20 days in a proportion of natural population. However, longevity in field is directly dependent on various ecological factors.

13.3.8 Environmental and Ecological Factors

The prevalence of vector is dependent upon the environmental factors which include humidity, temperature and rainfall. The ecological factors like alluvial soil, *kuccha* mud-houses and large-scale vegetation also influence buildup of vector density.

SAQ 1

Fill in the blanks.

i) The life cycle of *Phlebotomus argentipes* consists of 4 stages namely eggs, larva, ………………… and ………………… .

ii) Freshly laid eggs of sandflies are creamy white in colour which gradually turn to ………………… .

iii) Sand flies are natives of ………………… climate.

iv) Female sand flies feed on a wide variety of ………………… hosts.

v) Prevalence of vector is dependent upon the environmental factors such as humidity, temperature and ………………….. .

13.4 SAND FLY-BORNE DISEASES

Visceral leishmaniasis is a chronic disease caused by *Leishmania donovani*. It is a visceral infection of reticulo-endothelial system.The parasite may be found in abundance in bone marrow, spleen and liver.Post Kala-azar Dermal Leishmaniasis (PKDL) is a condition in which the *Leishmania donovani* invades cells of skin and causes lesions.

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

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

Cutaneous leishmaniasis commonly known as oriental sore is caused by *Leishmania tropica.* In some of treated cases of Kala azar which recover from visceral infection or systematic disease, whitish spots develop in the skin which may grow into different shapes and sizes. This manifestation of *Leishmania donovani* presence in human body is known as Post Kala azar Dermal Leishmaniasis (PKDL)

Beside *Leishmania tropica*, *L. major* and *L. aethopica* also cause cutaneous leishmaniasis in different parts of the world. *Phlebotomus sergenti* is considered to be the principal vector of Anthroponotic cutaneous leishmaniasis*. Phelobomotus papatasiha* is not *incriminated as vector* for *zoonotic cutaneous leishmaniasis* (Table 13.1).

Table 13.1: Diseases Transmitted by *Phlebotomines* Species.

Visceral leishmaniasis	Cutaneous leishmaniasis
Causative agent: *Leismania donovani* Vector: *P. argentipes*	1. Anthroponotic or urban cutaneous (ACL); Causative agent (pathogen): *L. tropica* Vectors: *P. sergenti, P. papatasi*.
	2. Zoonotic or rural cutaneous (ZCL) Causative agent : *L. major* Vector : *P. salehi* Reservior : *Meriones hurrainae*

13.4.1 Visceral Leishmaniasis (VL)

Visceral leishmaniasisis caused by *Leishmania donovani* and is also known as Dum-Dum fever, Asian fever, Assam fever or infantile splenomegaly in various parts of the world. The pathogen is an obligate intracellular parasite of man and other mammalian hosts. It exists in two forms

- Amastigote form: found in humans
- Promastigote form: found in sand fly

(a) Amastigote form: It is the non-flagellar stage of the parasite, found inside monocytes, polymorphonuclear leucocytes or endothelial cells of human beings. These are small, round to oval bodies measuring 2-3 µm long with an oval/round nucleus in the middle. A rod-shaped kinetoplast lies at the right angles to the nucleus, which comprises of DNA containing body and a mitochondrial structure. The axoneme (rhizoplast) arises from the kinetoplast and extends to margin of the body. The amastigote divides by binary fission.

(b) Promastigote form: These are found in the digestive tract of sand fly. The fully developed promastigotes are 15-25 µm long, slender and spindle-shaped. The body has a single centrally located nucleus and a kinetoplast which lies transversely near the anterior end. The flagellum is single, delicate and measures 15- 28 µm and may be of same length as the body or even longer.

Life Cycle of *Leishmania donovani*

The female sand fly transmits the metacyclic promastigote form of the parasite while taking blood meal of man or other vertebrate hosts (the motile, elongated, extracellular form, flagellated). These promastigotes are immediately phagocytized by macrophages and other types of mononuclear phagocytic cells and transform into the amastigotes (aflagellated forms). The amastigotes multiply by simple binary fusion inside Reticulo endothelial system to form large number of amastigotes. The infected cell eventually becomes packed with the parasite, gets enlarged and ruptures. The liberated amastigotes infect new cells and the cycle is repeated and proceed to infect other mononuclear phagocytic cells. Some of the free amastigotes are phagocytosed by the neutrophils and macrophages in the blood stream (Fig. 13.6).

Free amastigotes are ingested by female sand fly during a blood meal from infected host. These enter the midgut of sand fly and transform into metacyclic promastigotes through procyclic and metacyclic intermediate forms. These promastigotes multiply by binary fusion and produce large numbers of promastigotes in lumen. After a period of 6-9 days, the promastigotes migrate from the midgut to the pharynx and then to buccal cavity of the sand fly. The sand fly transmits the infection to new host and the life cycle is repeated.

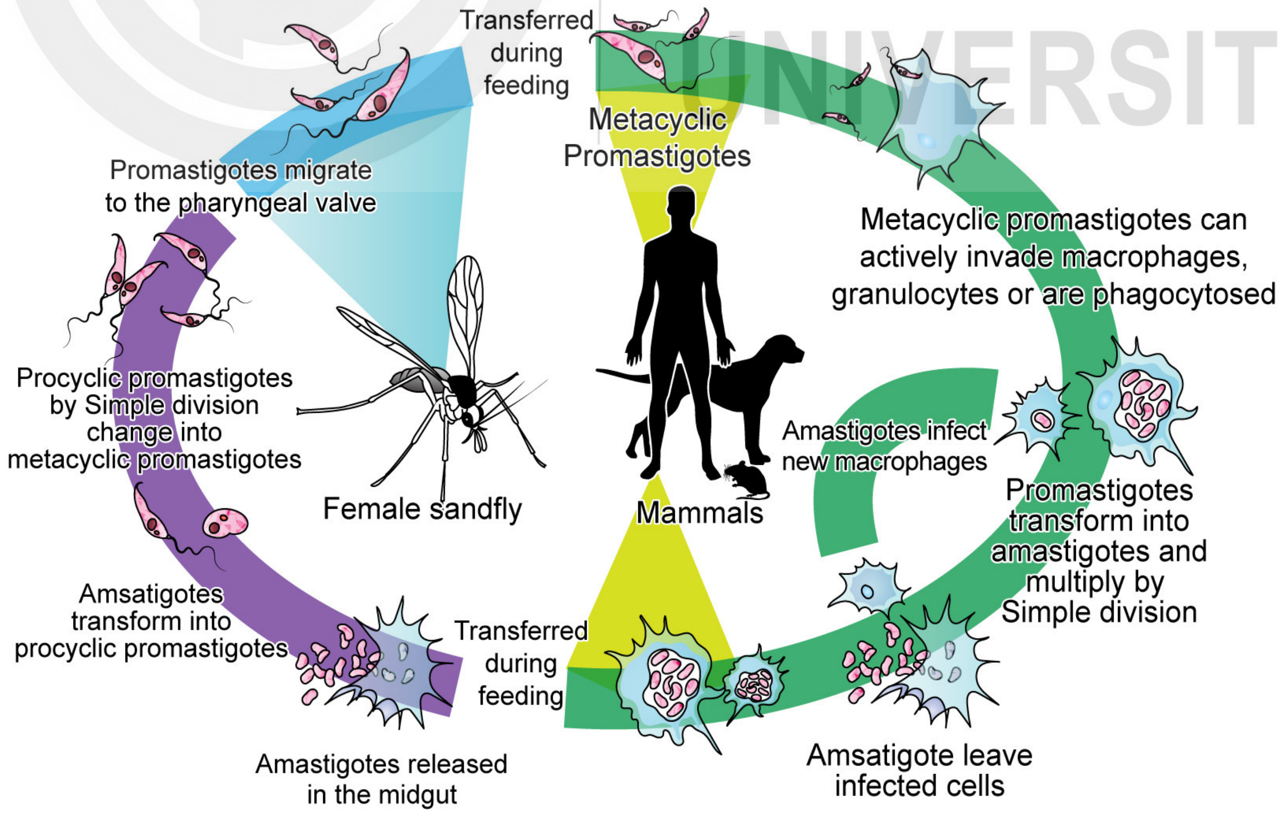

Fig. 13.6: Life cycle of *Leishmania donovani*.

Mode of transmission

The infection is transmitted to humans mainly by the bite of *Phlebotomus argentipes*. The infection may also be transmitted sexually and by blood transfusion, congenital infection and, accidental inoculation of cultured promastigotes in the individuals.

Pathogenicity

The parasite causing visceral leishmaniasis affects the RE system of human beings. Parasitized macrophages disseminate the infection to all parts of body but more to the spleen, liver and bone marrow. The spleen is enlarged, soft and fragile with a thickened capsule. The vascular spaces dilate and get engorged with blood. The reticular cells are markedly increased and packed with the amastigote forms of the parasite. In the liver, the Kupffer cells increase in size and number due to infection with amastigote forms. Bone marrow turns hyperplastic and parasitized macrophages replace the normal hemopoietic tissue.

Clinical symptoms

The common symptoms include fever, splenomegaly (enlarged spleen), hepatomegaly, (enlarged liver), jaundice, anemia, leucopenia (low count of WBCs), thrombocytopenia (low count of platelets) and skin lesions.

13.4.2 Cutaneous leishmaniasis (CL)

The cutaneous leishmaniasis is caused by *L. tropica* and spread by *P. sergenti* and *P. papatasi*. It is also called as oriental sores.

The disease is characterized by lesions that range from pimples to large ulcers located on the skin of the legs, feet, hands, and face, most of which heal spontaneously after many months. The lesion often ulcerates and may become secondarily infected with bacteria.

13.4.3 Phlebotomus Fever

Sand fly fever, also known as Pappataci fever, Phlebotomus fever or 3-day fever is an interesting disease mimicking other conditions which cause fever, myalgia and malaise along with abnormalities in liver enzymes and hematological test results.

The disease is caused by Phlebovirus carried by sand fly. After a few days of the infective bite, the abdominal distress and chills develop followed by fever of 39 °C to 40 °C, severe frontal headaches, muscle and joint aches, flushing of the face and a fast heart rate. After two days the fever starts subsiding and the temperature returns to normal. Fatigue, a slow heart rate and low blood pressure may persist from few days to several weeks before complete recovery.

13.5 CONCEPT OF KALA-AZAR ELIMINATION IN INDIA

In India, the sand fly population build-up took place in the 1970s after withdrawal of control measures from erstwhile malaria endemic areas, ultimately leading to resurgence of Kala-azar. The resurgence was initially in four districts of Bihar and slowly spread to entire North Bihar, some parts of Jharkhand and several districts of West Bengal. Sporadic incidence was reported from a few districts of Uttar Pradesh in the 1980s.

13.5.1 Kala-azar Control Programmes

Concerned with the increasing incidences of Kala-azar in the country, the Government of India (GoI) launched a Centrally Sponsored Kala-azar Control Programme in the endemic states in 1990-91 with the following objectives:

(a) Interruption of transmission by reducing vector populations twice in a year;

(b) Early detection and complete treatment of cases;

(c) Health education programme for community awareness, Information Education Communication (IEC) and Behavior Change Communication (BCC).

Government of India provided drugs, insecticides and technical support; while state governments provided costs involved in implementation. The programme was implemented through State / District Malaria Control organizations and the Primary Health Care (PHC) system. With above strategies the programme achieved significant decline in Kala-azar cases and mortality, but could not sustain the pace of decline for long. To overcome the situation, GoI further strengthened Kala-azar programme which led to improved case detection through the Primary Health Care (PHC) system resulting in decreased incidence of Kala-azar cases and deaths. By 1995, there was a 70.7% decline in annual incidence of cases and 80.5% decline in deaths as compared to 1992. By 2003, there was a 76.4% decline in annual incidence and 85.2% decline in deaths as compared to 1992.

The National Health Policy (2002) set the goal of Kala-azar elimination in India by the year 2010, however, later revised in 12th Five Year Plan document to 2015. The main objective of Kala-azar elimination programme was to reduce the annual incidence of Kala-azar to less than 1 case per 10,000 population at block Primary Health Centre level.

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

13.5.2 Prevention and Control

As with many disease vectors, control requires (Fig. 13.7) an integrated approach that utilises a number of different methods and is tailored to the local situation. Phlebotomine sand flies are susceptible to several insecticides, such as organochlorines and pyrethroids. Resistance to several insecticides has been reported in some sand fly species.

Indoor residual spraying of houses and animal shelters is an effective control strategy in achieving the interruption of the disease transmission in peridomestic environments. The impact of IRS can be maximized if synchronized with case detection. The objective of IRS is to ensure safe and correct application of the insecticide to indoor surfaces of houses and animal shelters so as to obtain a marked reduction in vector populations and consequently a significant reduction of Kala-azar transmission in the target area. Application of insecticides to outdoor resting sites (if known) can also be effective.

Control of immature stages is difficult as the breeding sites of most species are unknown. Hygiene and sanitation in the surrounding areas is significant to control the vector breeding.

Fig. 13.7: Vector Control strategies of sand flies.

13.5.3 Personal Protection

The use of protective clothing, insect repellents and insecticide-impregnated bed nets are effective in reducing human-sand fly contact.

13.5.4 Habitat Reduction/Modification

Measures such as resurfacing walls to cover cracks and holes, demolition and removal of uninhabited buildings, and removal of organic waste and unwanted vegetation can help to discourage sand fly breeding. Destruction of the habitat of reservoir hosts, such as rodents that enable sand fly populations to establish, is also an effective control method.

13.5.5 Reservoir Control

The animals such as dogs and rodents act as reservoir hosts for disease. These can be culled in order to reduce disease transmission risk. **Deltamethrin-impregnated dog collars** are effective for preventing sand fly bites. These are a low-cost and more humane intervention device. The spray insecticide formulations can be applied on the spot to reduce biting sand flies.

SAQ 2

Match the Column A with Column B.

Column A	Column B
1) Visceral leishmaniasis	a) *Leishmania tropica*
2) Phlebotomus fever	b) Reservoir hosts for disease
3) Dogs and Rodents	c) Phlebovirus
4) Cutaneous leishmaniasis	*d) Leishmania donovani*

13.6 SUMMARY

Let us summarise what we have learnt so far:

- Leishmaniases are vector-borne infections transmitted by female sand fly and caused by a protozoan parasite of the genus *Leishmania*.
- Three main species of the genus cause different types of clinical manifestations in man.
- *Leishmania donovani* causes visceral leishmaniasis (Kala-azar), *L. tropica* causes cutaneous leishmaniasis and *L. braziliensis* causes the mucocutaneous leishmaniasis.
- Sand flies are grouped in two sub-families namely Psychodinae and Phlebotominae. Only the members belonging to family Phlebotominae are transmitting agents for different types of leishmaniases.
- *Phlebotomus argentipes* is the only known vector of visceral leishmaniasis.
- The pathogen *Leishmania donovani* exists in two forms; amastigote and promastigote.
- The common symptoms of visceral leishmaniasis include fever, splenomegaly, hepatomegaly, jaundice, anemia, leucopenia, thrombocytopenia and skin lesions.
- The cutaneous leishmaniasis is caused by *L. tropica* is characterized by lesions that range from pimples to large ulcers located on the skin of the legs, feet, hands, and face.
- Sand fly fever is caused by Phlebovirus carried by sand fly. The fever causes abdominal distress and chills followed by high fever, severe frontal headaches, muscle and joint aches, flushing of the face and a fast heart rate.
- Sand fly control requires an integrated approach. Indoor residual spraying of houses and animal shelters; sanitation, hygiene, personal protection, habitat reduction and reservoir control are effective control strategies in achieving the interruption of the disease transmission.

13.7 TERMINAL QUESTIONS

1. Name the diseases spread by sandflies.
2. Name any three species of sand fly found in India.
3. Write the ecological factors favourable for the transmission of Kala-azar.
4. Describe the life cycle of sand fly with well labelled diagram.
5. Discuss control measures for sand fly.
6. Illustrate the transmission of visceral leishmaniasis in human beings.

13.8 ANSWERS

Self Assessment Questions

1. i) pupa, adult, ii) dark, iii) warm, iv) vertebrate, v) rainfall.
2. i) d, ii) c, iii) b, iv)a.

Terminal Questions

1. Visceral leishmaniasis or Kala-azar, Cutaneous leishmaniais or Oriental sore, Phlebotomus fever or pappataci fever.
2. *Phelebotomus argentipes*

   Phelebotomus papatasi

   Phelebotomus sergenti
3. Alluvial soil

   High sub soil water

   Monthly mean maximum temperature below 37 deg. C

   Monthly mean minimum temperature above 7.2 deg. C

   Annual rainfall 1250 mm or more

   Mean Annual relative humidity of 70% for at least 3 months

   Abundant vegetation

   Altitude below 600 meters
4. Refer to Section 13.2.
5. Refer to Section 13.5.
6. Refer to Sub-Section 13.4.2.

UNIT 14

DIPTERANS AS DISEASE VECTORS-V (HOUSE FLIES)

Structure

14.1 INTRODUCTION

In the earlier units, you studied about mosquitoes and sand flies as the vector of human diseases. All these insects are sanguivorous and transmit diseases while feeding on human blood. In the present unit, we will discuss about the structure and medical importance of house fly, which neither bites nor stings yet it is one of the most harmful carrier of germs for various diseases.

The scientific name of housefly is *Musca.* Many *Musca* species are prevalent worldwide, among which *Musca vicinia, Musca sorbens, Musca domestica* and

Musca nebulo are most commonly found in India. *Musca* species can be found throughout the year in close association to man and can be regarded as a sign of insanitation.

Objectives

After going through this Unit, the learner will be able to:

- explain the characteristic features and biology of housefly,
- detail and draw the life cycle of housefly,
- explain the behavior of housefly,
- discuss the role of houseflies as vector of diseases, and
- describe the preventive and control measures of houseflies,

14.2 LIFE CYCLE OF HOUSEFLY

Houseflies are dipterans and belong to Muscidae family. Common housefly *Musca domestica* is worldwide in distribution. Originally from Asia, they are now found all over the world around hovering over human habitation, near garbage bins and dirty places.

They contaminate our food and water and are responsible for millions of infant deaths. The sponging type of mouthparts allow them to feed us on the liquid food. Housefly is holometabolous insect and thus its life cycle comprises egg, larva, pupa and adult stage.

14.2.1 Adult

Housefly has a greyish and slightly hairy body with a yellowish tinge on the ventral surface. Like any other insect, the body is divisible into head, thorax and abdomen.Head bears a pair of antennae (aristate type), a pair of red-coloured compound eyes and three small simple eyes or ocelli. The compound eye is adapted for diurnal vision. They have sponging type of mouth parts to suck the liquid food by capillary action (you have already studied about these mouth parts and feeding mechanism in unit 2).

The thorax has 2-4 dark longitudinal stripes which is characteristic of the genus *Musca*. The three segments of the thorax (prothorax, mesothorax and metathorax) are not clearly demarcated. Each thoracic segment bears a pair of legs, longer in males than females. The terminal end of each leg bears a pair of curved claws. In between these claws is present a pair of glandular pads having numerous short and stiff hair called the **pulvillus**. The hair secretes a sticky substance which helps them in walking. Specialized sensory chemoreceptors are present in the tarsus of each leg. These can identify sugary food and taste sweetness while walking over them.

Like all dipterans, houseflies also have one pairs of wings. The forewing is broad, transparent, hairy and triangular with a yellowish tinge at the base while the hind wing is reduced and modified into the balancing organ known as **halteres.** During flight the wings vibrate rapidly producing a characteristic buzzing sound. When at rest the wings fully cover the abdomen. The wings of female housefly are larger than that of males.

The abdomen is hairy, 10-segmented with light and dark markings. First segment is underdeveloped while last segment has a pair of anal cerci. The last three to four segments in males form a genital pouch while in females they form **ovipositor** for laying eggs. The copulatory organ of males, **aedeagus** or penis is present on the ninth segment.

Adult flies generally do not live longer than 15 days in summers and 25 days in winters. The fly overwinters in the larval or pupal stage. They are most active during the hot summer months and breed from June to October. Breeding period is at its peak from August to September.

14.2.2 Eggs

The female fly lays eggs a week after copulation. A female can lay 500-700 eggs in 5 or 6 batches of 100-150 eggs each. The eggs are laid in decaying fruits and vegetables, rotting organic manure, garbage, human and animal excreta and debris where they get warmth, sufficient moisture and protection. Indian species of *Musca domestica* and *Musca vicinia* prefer to breed on human excreta. The ovipositor helps in digging the organic matter and laying eggs.

Fig. 14.1: Egg laying by a housefly

Eggs are white in colour, elongated with a curved dorsal thickening. They are about 1mm long and hatch in 8-24 hours. In summers, the eggs can hatch even in 3 hours.

14.2.3 Larvae

A soft, about 2mm, white, apodous (legless)and acephalous (headless) larva emerges out by making an elongated dorsal slit on the egg case. The larva of housefly is known as **maggot**. The anterior end of the maggot is narrower than the posterior end. A chitinous cuticle covers the body of the larva externally.

The body of the maggot is divided into thirteen segments. The anterior segment contains two oral lobes. Each oral lobe has two sensory tubercles and many branched food channels. Mouth is present between the oral lobes. Spiniferous pads are present in each of the 6-12 segments which help in locomotion.

The first instar larva is approximately 3 mm long, creamy white, voracious feeder, very active and rapidly increases in size. It molts twice to become the third instar mature larva. Full grown larva may be about 7-12mm in length, and greasy, creamy white in colour.

Fig. 14.2: Housefly maggots feeding on manure

The larva requires oxygen for its survival and thus are found in places where there is plenty of fresh air. They avoid light and bury themselves in the rotten moist manure heap. They can penetrate up to a depth of few meters. The optimal temperature for larval development is 35 to 38℃, though larval survival is greatest at 17 to 32℃. The larval period lasts for about 2 to 7 days but may be prolonged in winters.

14.2.4 Pupae

The full-grown larva stops feeding, defecates, shrinks in size and migrates to the dry region of the manure heap or other protected places. It then encloses itself in a hard pupal case formed by the last larval skin and converts to the pupa. Only the spiracles project out from the posterior end for breathing.

Pupa is barrel-shaped with blunt round ends and dark brown in colour. Within the hard covering, rapid changes take place and all the larval structures are broken down by histolysis except for the nervous system. New structures are formed from special cells called imaginal disc. When all the structures are fully formed a young colorless fly emerges out from the pupal case.

Pupal period lasts for about 3 to 6 days but this can also be prolonged in winters.

The newly formed fly has rudimentary delicate wings and short legs. However, in a short duration of time, different parts develop, wings become fully expanded, and become hard on exposure to air, and a fully mature adult is formed.

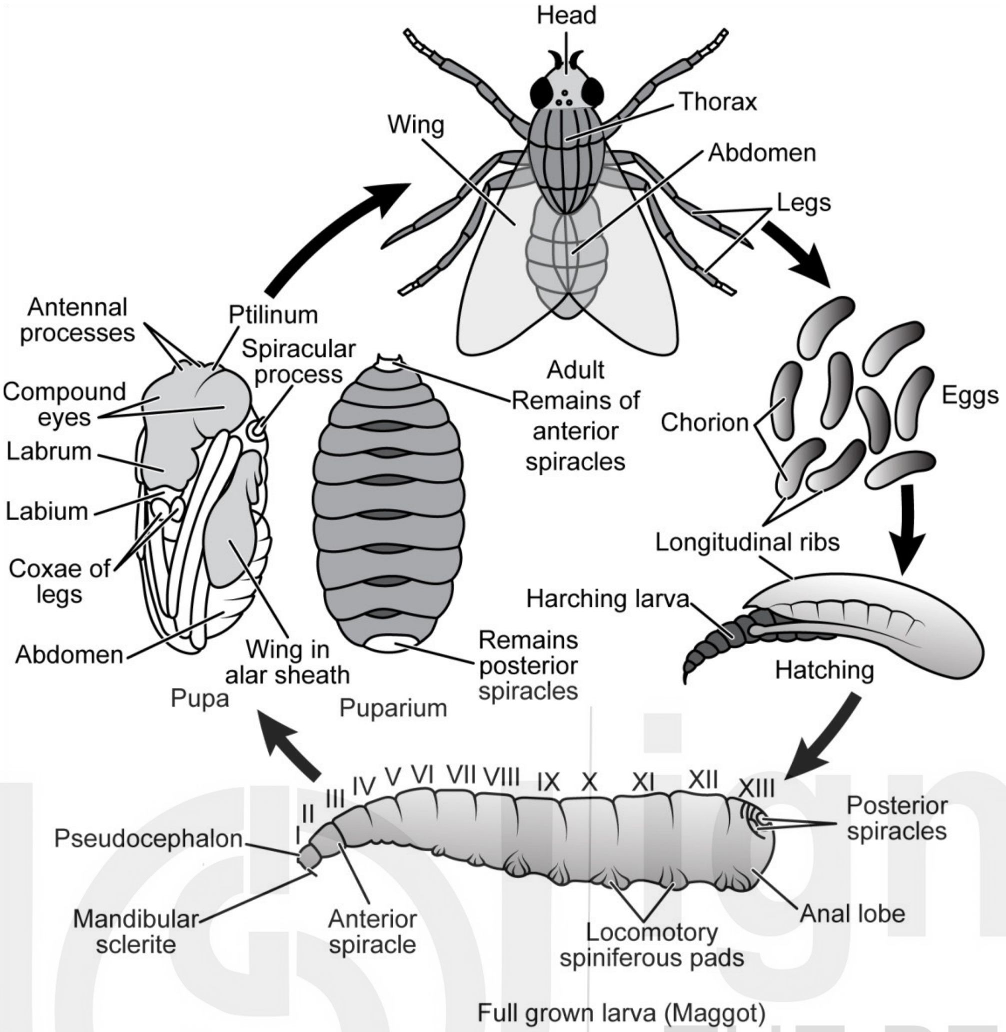

Fig. 14.3: Life cycle of *Musca nebulo*

The life cycle of house fly may be completed in 5-6 days at optimum conditions in summers which can be prolonged to 8 to 20 days depending on the temperature. However, it may extend to about two months under suboptimal conditions. The common house fly may have about 20 generations in a year in tropical and subtropical regions and about 10-12 generations in temperate regions.

SAQ 1

i) Fill in the blanks:

a. The scientific name of common housefly is ....………..…, ………………..

b. The optimum temperature for housefly development is ………… .

c. The reduced hindwings of house fly are called ……………….. .

ii) Read the following statements and State whether ‘True’ or ‘False’:

a) The male copulatory organ of *Musca* is known as aedeagus.

b) Image in houseflies is formed by the ommatidia present in ocelli.

c) Pulvillus helps the fly in flying.

iii) Read the following sentences and choose the correct option given in the parentheses:

a. The larva of house fly is known as (maggot/ caterpillar/ wriggler).

b. House fly lays eggs in (stagnant water/decomposing organic matter/ honey comb).

c. Larvae of housefly are (apodous/oligopodous/polypodous).

d. The adult house fly which emerges from the puparium is known as (imago/ tumbler/ptilinum).

e. Spiniferous pads help the larva in (feeding/ respiration/locomotion).

14.3 BEHAVIOR

14.3.1 Activity

Houseflies are **diurnal** and are very active during the day in bright sunlight. The maximum activity of flies can be observed at a temperature of 25-30°C and at low humidity. They prefer to rest at 40-45°C or at very low temperatures of 10-15°C. At very low temperatures, the species can stay alive in a dormant state in the adult or pupal stage.

In a given locality, fly numbers vary with the availability of breeding places, daylight hours, temperature and humidity.

14.3.2 Resting

When not feeding, they rest near garbage bins, on floors, windows, ceilings, grass, hedges, bushes, clothes lines, electric wires, latrines and filthy places.

At night, flies are normally inactive and rest at ceilings, other overhead structures and outdoor sites such as fence, clothes lines, electric wires, weeds, grasses, hedges, bushes and trees. The resting places are generally near the breeding areas.

14.3.3 Feeding

They have sponging type of mouthparts and feed on liquid food. If the food is solid, the fly pours its saliva or regurgitates its liquid content from the crop over it, liquifies it and then sucks the liquid food. They feed very frequently.

14.3.4 Oviposition

Nutrient-rich substrates provide an excellent developmental substrate. Thus, the flies lay eggs in decaying fruits and vegetables, rotting organic manure, garbage, human and animal excreta and debris. The developmental stages get warmth, sufficient moisture, nutrients and protection.

Houseflies also breed in sewage sludge and solid organic waste in open drains, underground pools for sewage and cesspits.

14.3.5 Visual Response

Visual stimulus is one of the most important determinants in fly behavior. Houseflies rely on reflected sunlight to detect objects in their environment while flying, finding food, searching for harborage and resting areas.

It has been reported that flies response maximally to white and blue colours followed by yellow, red, green, and black. In fact, a tendency to repel by yellow colour has also been shown by flies.

14.4 HOUSEFLY-THE MECHANICAL VECTOR

The housefly is a mechanical vector of many pathogens-virus, bacteria, protists, fungi and nematodes. The fly picks up disease-causing organisms while crawling and feeding.

14.4.1 Transmission of Diseases

Transmission takes place when the fly makes contact with the people or their food. Most of the diseases can also be contracted more directly through contaminated food, water, air, hands and person-to-person contact. The housefly can transmit disease in the following ways.

1. **Contact transmission:** The houseflies carry the microorganisms, eggs and cysts of various parasites on their feet, hairy legs and other parts of the body and deposit them on our food and drinking water causing infection.
2. **Vomit drop (Regurgitation):** The housefly has a habit of frequent regurgitation while sitting on food items and water. This regurgitated stomach content contains rich bacterial culture which infects our food and water.
3. **Defecation:** The excrement of housefly has been found to contain many microorganisms, cysts and eggs of intestinal parasites and thus acts as a source of the transmission of diseases.

The pathogens that stick to the outside surfaces of the fly may survive for only a few hours, but those that are ingested with the food may survive in the fly's crop or gut for several days.

Houseflies are the potential vector for diseases like typhoid, paratyphoid fever, cholera, gastroenteritis, amoebiasis, salmonellosis, diarrhea, dysentery, anthrax, tuberculosis, trachoma, yaws (a chronic bacterial infectin that affcts the skn,bone and cartiage), and conjunctivitis. Eggs and larvae of tapeworm (*Taenia*) and roundworm (*Ascaris*) may be transmitted by housefly.

14.4.2 Myiasis

Myiasis is caused by the invasion of the body parts of humans or animals by the housefly eggs or larvae.

Houseflies can oviposit on or in human tissues if personal hygiene is not maintained. The flies sometimes can lay eggs on open wounds, nasal passage, anus, vagina, eyes etc. The larvae that hatch out cause serious disorders. Eggs and larvae ingested with contaminated food and water can cause intestinal disorders.

Signs and Symptoms

The symptoms of myiasis depends upon the area invaded by the larvae. A few types and the symptoms of the disorder are as follows.

a) **Cutaneous myiasis:** The maggots invade the skin and form painful ulcers that can last for long time.

b) **Nasal myiasis:** Maggots enter the nasal passages and obstruct them causing severe irritation. It can also result in facial edema and fever.

c) **Aural myiasis:** The larvae cause crawling sensations and buzzing noises in the ears. Entry of larvae in the middle ear can make their way to the brain.

d) **Ophthalmomyiasis:** Myiasis in the eyes cause severe irritation, edema, and pain.

e) **Intestinal myiasis:** Myiasis of the gastrointestinal tract may be asymptomatic or can lead to abdominal pain, vomiting, and diarrhea.

Others include urinary myiasis, migratory myiasis, vaginal myiasis, oral myiasis etc.

SAQ 2

i) Fill in the blanks with appropriate words.

   a) Houseflies have ………… type of mouth parts (biting/sponging).

   b) The excellent developmental substrate for houseflies is rich in ………………. (moisture/nutrients).

   c) ………………… myiasis forms painful ulcers (aural/cutaneous).

   d) Houseflies transmit diseases ………… (mechanically/biologically).

ii) State whether the following statements are 'True' or 'False'.

   a) Houseflies response maximally to white and green colour.

   b) Houseflies are the most active during evenings and inactive in night.

   c) The housefly larvae invade various organs and cause disorders.

14.5 PREVENTION AND CONTROL

Houseflies and their breeding can be controlled by mechanical, cultural, biological and chemical methods. However, it is best to use all the four methods as an integrated approach.

14.5.1 Cultural Control

The best and the easiest method to control house flies is to eliminate their breeding places and take proper care of sanitation and hygiene, not only at home but also of the environment around us. It is not difficult to do it. Food and materials on which the flies can lay eggs must be removed, destroyed as a breeding medium, or isolated from the egg-laying adult .Let us list some of the ways by which we can improve our environmental sanitation.

1. Proper disposal of any organic matter, such as vegetable or other food by-products can prevent breeding of houseflies. All such materials should be put in the tightly tied garbage bags. Alternatively; garbage, kitchen waste or refuse should be stored in bins and covered with tight-fitting lids.

2. Waste should be finally disposed by incineration, composting or sanitary landfill.

3. Open air defecation should be prohibited. Instead, sanitary latrines should be used.

4. Sanitary disposal of animal excreta helps to control housefly breeding.

In general, good environmental sanitation on a community-wide basis and a clean house with a clean surrounding is the preliminary step in fly management.

14.5.2 Mechanical Control

Mechanical control methods for keeping the housefly under control are:

1. Screening or covering of windows, doors and trash containers proves useful in preventing breeding.

2. **Fly traps;** such as sticky traps, ultraviolet light traps and pheromone traps placed at different places in homes or in business places can reduce housefly population.

   a) Sticky traps can be prepared by coating a suitable device/flypaper with honey, sugar, fruit, molasses or any substance that attracts housefly. These flypaper/devices are hanged in infested areas where there is little or no air movement and are dark. It is advisable to place one 10-inch strip per 1,000 cubic feet of space within 6 feet of the floor because most fly activity is near the ground and should be placed in dark areas away from bright light. Care should also be taken to place these traps away from the food and kitchen area to avoid the risk of food contamination. The strips are generally effective for up to about 3 months.

   b) Ultraviolet traps have a grid of wires mounted in front of the UV fluorescent tubes. The UV light attracts the files, trap and kill by electrocuting them.

   c) The sex pheromone (Z)-9-tricosene, called as muscalure, functions as an aggregation pheromone. Muscalure is added with sugar as a commercially available fly bait for local population suppression, as well as enhancement for population monitoring.

14.5.3 Biological Control

Parasitic wasps and fire ants suppress housefly populations naturally. The parasitic wasps do not harm people or animals. They kill immature houseflies. However, parasitic wasps alone cannot eliminate a housefly population. This method can be used in combination with other methods.

14.5.4 Chemical Control

- Insecticides can help suppress housefly populations.
- Fly baits, such as QuickBayt® and Golden Malrin®, are usually sugar-based and contain a compound that attracts the adult flies. Flies that feed on these baits are killed by the insecticide.
- Neem leaves and carbolic acid are good repellents for controlling flies. Fumigation can be done with dry neem leaves or carbolic acid. Repellents like creosote oil and borax solution sprinkled in animal sheds and other breeding places of the housefly are effective in controlling the fly population.
- Spraying of 2% malathion or diazinon, 1% chlordane or 0.5% dieldrin are effective insecticides for killing the flies.
- Anti-fly candles can be prepared by mixing pyrethrum, saw dust, wheat flour and potassium nitrate in the ratio of 5:1:2:2w/w and rolled into a candle. Burning of anti-fly candles gives a quick knock-down effect to the flies.
- Manure can also be treated with an insecticide, though this method is highly discouraged as it can be lethal to the biological control agents of flies.

SAQ 3

Match the following:

Column 'A'	Column 'B'
i) Cultural Control	a) Fly baits
ii) Biological Control	b) Fly traps
iii) Chemical Control	c) Sanitation and hygiene
iv) Mechanical Control	d) Fire ants

14.7 SUMMARY

Let us summarise what we have learnt so far:

- The common housefly is a diurnal insect found in filthy dirty places and human habitation.

- The housefly possesses sponging type of mouth parts to suck the liquid food.
- Adult body is divisible into three distinct regions *viz*. head, thorax and abdomen.
- Hindwings are greatly reduced to form halteres which act as balancing organs.
- Glandular pads, pulvillus, are present on the legs in between the claws which enable the fly to walk on the walls or ceilings.
- Males have aedeagus, the copulatory organ, on the ninth abdominal segment.
- Ovipositor of female receives the sperms during copulation and help in egg laying.
- Development is indirect with complete metamorphosis (holometabolous).
- Eggs are white in colour, elongated with a curved dorsal thickening.
- Larval form, called maggot is legless, headless and passes through three instars.
- The first and second instar larvae feed on organic matter and debris voraciously.
- Pupa is enclosed in a pupal case called puparium and emerges into adult within 3 days.
- Adult flies generally do not live longer than 15 days in summers and 25 days in winters. The fly overwinters in the larval stage or pupal stage.
- Nutrient-rich substrates provide an excellent developmental substrate for the flies where they get warmth, sufficient moisture, nutrients and protection.
- Houseflies rely on reflected sunlight to detect objects in their environment while flying, finding food, searching for harborage and resting areas.
- The housefly is a mechanical vector of many pathogens-virus, bacteria, protists, fungi and nematodes.
- It is a potential mechanical vector for diseases like typhoid, paratyphoid fever, cholera, gastroenteritis, amoebiasis, salmonellosis, diarrhea, dysentery, anthrax, tuberculosis, trachoma, conjunctivitis and yaws.
- Eggs and larvae of tapeworm (*Taenia*)and roundworm (*Ascaris*) may be transmitted by housefly.
- Contact transmission, vomit drop and defecation are three different ways in which housefly can transmit the diseases.
- Laying of eggs on or in human tissues can cause myiasis in which larvae invade body parts of humans and cause serious disorders.

- Eggs and larvae ingested with contaminated food and water can cause intestinal disorders.
- Mechanical, cultural, biological and chemical control methods can be used to keep a check on the housefly population. The integrated approach provides best result to control their population.

14.7 TERMINAL QUESTIONS

1. Explain the economic importance of housefly.
2. Write short notes on:
   a) Traps used for controlling houseflies
   b) Cultural control of *Musca*
   c) Chemical control of housefly
   d) Myiasis
3. Explain the life cycle of *Musca nebulo* with the help of a neat labelled diagram.
4. What are the different ways by which a house fly can transmit diseases?
5. Write the identifying features of adult *Musca* sp.
6. What is the role of halteres in house fly?
7. What type of mouth parts do the house fly possess and how is it beneficial to them?
8. List five diseases for which house fly acts as a mechanical vector.
9. With the help of an example explain the role of biological control in keeping a check on the housefly population.
10. What are anti-fly candles?
11. List five control measures that you will take at home to keep the flies away.

14.8 ANSWERS

Self Assessments Questions

1. i) a) *Musca domestica;* b) 25-30°C; c) halters.
   ii) a) True; b) False; c) False.
   iii) a) Maggot; b) decomposing organic matter; c) apodous; d) imago; e) locomotion.
2. i) a) sponging; b) nutrients; c) Cutaneous; d) mechanically.
   ii) a) False; b) False; c)True.
3. i) c, ii) d, iii) a, iv) b.

Terminal Questions

1. Write about the losses incurred by the houseflies and the amount of money spent by you to keep the flies away from you and your house. You have to keep in mind the involvement of economics while dealing with the flies.

2. a) Refer to Section 14.5.2.

   b) Refer to Section 14.5.1.

   c) Refer to Section 14.5.4.

   d) Refer to Section 14.4.2.

3. Refer to Section 14.2.

4. Refer to Section 14.4.1.

5. Refer to Section 14.2.1.

6. Refer to Section 14.2.1.

7. Refer to Section 14.3.2.

8. Refer to Section 14.4.1.

9. Refer to Section 14.5.3.

10. Refer to Section 14.5.4.

11. Refer to Section 14.5.

UNIT 15

INTEGRATED VECTOR MANAGEMENT (IVM)

Structure

15.1 INTRODUCTION

In the previous units, you studied about different dipterans as the vectors of the diseases. In this unit, we will discuss regarding the integrated vector management, its concept and application in the field. Integrated vector management (IVM) is, in fact, a rational decision-making process to optimize the use of resources for vector control. It requires a management approach so that it improves the efficacy, cost effectiveness, ecological soundness and sustainability of vector control interventions with the available tools and resources. Integrated approach is vital in successfully combating vector-borne diseases. There are various key elements of IVM comprising advocacy, social mobilization, strengthening of regulatory and legislative controls for public health, empowerment of communities, collaboration within health and other sectors for planning and decision-making, use of available resources for vector control, implementation of evidence-based strategies and capacity-building as well.

The prevention and control of malaria, filariasis, dengue fever, Japanese Encephalitis, and leishmaniasis are linked closely to various ecological factors. However, control measures are dependent mainly on the anti-vector operations which are carried out as a component of national program of vector-borne diseases. Great emphasis is being laid on the organization, system and strategy. The government programmes are coverage-oriented, and not result-oriented. Very often, failures encountered in the control programmes are largely due to lack of operational and managerial skills rather than technical know-how. In addition, many national vector control operations have been facing technical difficulties on account of increased insecticide resistance in many vector species and operational difficulties due to higher cost of the alternative insecticides. Therefore, the benefit of integrated vector control approach has been widely recognized and a variety of control methods/agents are available for use.

Objectives

After studying this unit you should be able to:

- ❖ define Integrated Vector Management,
- ❖ list the elements of IVM,
- ❖ explain different types of vector control methods, and
- ❖ describe the activities of different sectors for IVM.

15.2 INTEGRATED VECTOR MANAGEMENT (IVM)

The selection of priority target species for implementing control measures depends on the local conditions, such as vectorial status, Insecticide resistance, and exophilic and exophagic behavior that can render the indoor residual spraying inappropriate. Restricted and well-defined vector breeding habitats are located in urban and semi-arid conditions. Some important vectors amenable to this approach are as follows:

- *Aedes aegypti*, in domestic containers,
- *An. stephensi* in urban wells and reservoirs,
- *An. culicifacies* in irrigation canals and pools,
- *An. sundaicus* in lagoons and swamps,
- *Culex. quinquefasciatus* in polluted urban habitats.

There are many specific elements of IVM which include:

- Micro-stratification to identify paradigms and tools of integrated vector management (Fig. 15.1),

- Forest, irrigation, industrial, foothills, forest fringe, urban and peri-urban areas,
- Determination of the dynamics and risk factors of transmission
- Control by utilizing old/new tools synergistically – not overlapping
- Rational use of insecticides
- Functional inter-sectoral co-ordination set up for implementation and for resource sharing
- Community participation
- Collaboration with the health sector and other public and private sectors
- IEC (Information, Education and Communication) activities
- Capacity building
- Monitoring and evaluation
- Good management practices

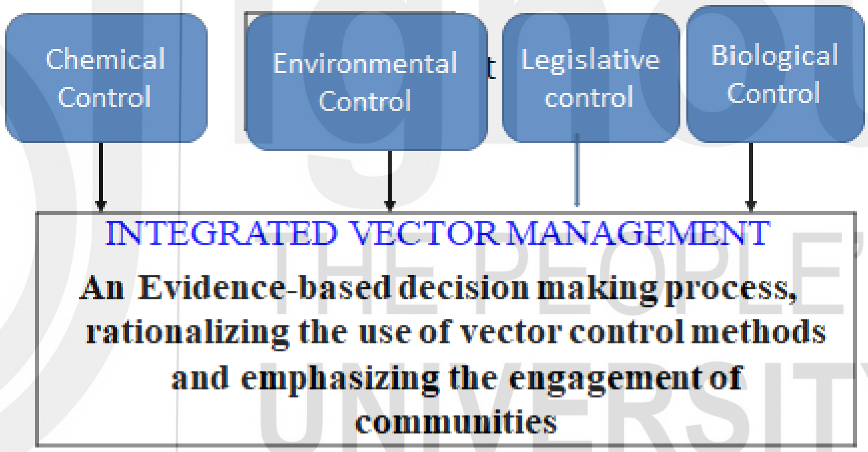

Fig. 15.1: Judicious use and selection of Vector Control Option.

Fig. 15.2: Source reduction – elimination of *Aedes aegypti* breeding at weekly interval including use of Petroleum oil/ Kerosene oil/ Temephos. Mosquito proofing of water tanks (overhead & ground tanks), buildings.

15.3 SOURCE REDUCTION

Environmental methods of controlling mosquito breeding include source reduction methods, *i.e.,* reduction of their breeding sites by filling ditches, pits, low lying areas, streamlining, canalizing, desilting, de-weeding, trimming of drains, water disposal and sanitation, emptying water containers once in a week (Fig. 15.2).

Source reduction methods based on elimination of breeding sites can be classified into following activities.

15.3.1 Filling

Filling can be done on minor scale for elimination of burrow pits, ditches, small unused irrigation canals and unused/abandoned wells in and around human habitations/villages for prevention of mosquito habitats. These activities can be easily undertaken by field workers employed for routine activities. Filling operations should be undertaken only after evaluation of prevailing vector mosquitoes and their breeding behavior. Garbage is often used for filling the pits after consideration of hygiene, fly nuisance and offensive smell. Sanitary land fill method is also recommended which is achieved by dumping a layer of refuse/garbage in the area followed by earth cover daily after compaction. Land thus reclaimed not only prevents vector breeding but also can be used as recreational park, playing ground and storage. The sediments carried by runoff streams or collected during rainfall can be used as natural filling material for permanent elimination of intermittently flooded areas or swaps.

15.3.2 Drainage

Drainage is used in eliminating breeding sites by draining away the water collections or reducing vector breeding by channeling water to other places which can be easily controlled. Construction of surface ditches, sub-surface drains, vertical drains, pumps and tide gates are some of the methods used in drainage (Fig. 15.3). Type of best suited ditch or drain depends upon topography, source of water, soil properties and the availability of funds. The types of drainage are discussed below:

Surface ditches: Ditching is the most widely used method of drainage in source reduction programmes. The cost of construction is modest and benefits are considerable. However, regular maintenance is necessary to ensure adequate flow capacity and channel improvements to prevent creation of mosquito breeding pockets.

Sub-surface drains: Well-designed sub-soil drainage requires a minimum of maintenance and can function satisfactorily for many years. The concrete or clay pipes are used for small scale installation, while concrete pipes are used for large installations.

Vertical drains: These drains are effective when water is held on the surface by an impervious stratum (surface) overlying on a pervious surface. A hole is bored through the impervious layer to drop the water on pervious layer for drainage. When installing vertical drainage, local sanitary authorities must be consulted regarding the danger of contaminating subsurface water supplying the water wells.

15.3.3 Drainage in Irrigation Schemes

Source reduction measures in irrigated areas required water management by various ways, such as diversion of water, effective distribution system, drainage of excess water, or keeping a dry day in a week's irrigation. Under **Coastal drainage**; drainage of coastal swamps and lagoons requires care in design and construction of sea outlets.

In **Drainage by tide gates**; the gates are used for drainage of salt marshes along the sea. The gates are opened at low tide to allow water to flow out and closed at high tide to prevent sea water from flowing in.

Drainage by pumps: Water accumulating in low lying areas can be pumped out by installation of temporary diesel or electric pumps.

15.3.4 Prevention of Water Collection

Prevention of clean water collections is an easy to implement technique. The thrown away disposable/used containers, such as cups, glasses, buckets, tyres, utensils act as potential breeding sources for vector mosquitoes in monsoon. Open tanks, overhead/underground tanks and unused wells are also potential breeding source for mosquito vectors (Fig. 15.3). Similarly, construction sites, concrete roof and terrace without proper drainage may collect water during monsoon months forming breeding sites.

All these breeding sources should be controlled for comprehensive source reduction. A few steps include:

a) Any containers capable of holding water should be thrown in open.

b) The overhead and underground tanks should be properly covered. Their lids must be checked regularly.

c) Construction sites should be checked regularly to prevent water collection. Building constructions laws must be implemented to prevent water logging on the roof.

d) Unused wells either be closed or treated with larvicides. Wells in use may be covered with mosquito nets.

Fig. 15.3: Environment Management.

SAQ 1

Fill in the blanks.

i) Filling can be done on minor scale for the ………………………….. (elimination/modification) of burrow pits.

ii) The ……………………. (clay/concrete) pipes are used for large sub-surface drains.

iii) Ditching is the most widely used method of water …………………... (drainage/collection) in source reduction.

iv) Water is held in the surface by an ………………… (pervious/impervious) stratum.

v) Water accumulates in the …………………… (low/high) lying areas and cannot be drained out.

vi) Gates are opened at ……………… (low/high) tide to allow water to flow.

15.4 MECHANICAL CONTROL

Mechanical measures include the direct or indirect methods that control the vectors by making environment unsuitable for their entry, dispersal, survival or reproduction.

The sustainable vector control can be achieved by providing artificial ovitraps or breeding grounds utilizing common household utensils. The larvae can be thrown away in dry places or can be controlled biologically (will be discussed in Section 15.5), or by layering oil or plastic sheet over the water surface in order to suffocate them.

Various traps have been designed to catch disease vectors. High tension electric wires are used to attract houseflies, mosquitoes, etc. and kill them by electrocution. The traps containing stale cake to attract houseflies have been found useful. Attractive baits containing sugary juices are being explored to catch mosquitoes in the field.

Some newer mosquito traps emit carbon dioxide together with other mosquito attractants such as sugary scents, lactic acid, warmth, water vapor and sounds. The trap draws female mosquitoes by mimicking a mammal's scent, where they are sucked by an electric fan and are collected into a holder. A low-cost trap called 'Ovillanta' has been designed by Laurentian University which consists of attractant-laced water in the discarded rubber tire. The water is run through a filter at regular intervals to remove any deposited egg and larva. Windows, doors and ventilators of houses are screened to keep away mosquitoes, houseflies, etc.

15.5 BIOLOGICAL CONTROL

Biological control of vectors employs natural enemies or competitors, for example, parasites, predators, pathogens etc., either by introducing new species into the vector habitat or by increasing the effectiveness/density of those already present to reduce vector density and hence disease transmission.

15.5.1 Fish and Other Animal as Control Agents

Fishes have widely been used in public health, since as early as 1903. One of the most successful and widely used biological control agents against mosquito larvae is the fresh water minnow or mosquito fish *Gambusia affinis*. Fish other than *Gambusia* which has received the most attention as a mosquito control agent is *Poecilia reticulata*, the common guppy (Fig. 15.4).

The states have been advised to upscale the use of fish as biological control method in rural areas.

Apart from these, the biological control agents of mosquitoes include immature stages (naiads) of mayflies and dragonflies, mermithid worms, (*Romanomermis culicivorax*), copepods, notonectid bug. Lizards, gecko,etc. You have learnt about these in previous units.

a) b)

Fig. 15.4: a) *Poecilia reticulata* (GUPPY) and b) *Gambusia affinis*.

15.5.2 Microbial Control

Biological control using pathogens is now termed as **microbial control.** The term was coined by Steinhaus in 1949 for using disease-causing microorganisms to control pests and vectors. Collectively called, entomopathogens, these include bacteria, virus, fungi and protozoans.

The bacterial larvicides employing *Bacillus sphaericus* have been used to target and kill vector larvae without generating the ecological impacts of chemicals. The toxins produced cause gut paralysis and purging of the intracellular content of gut epithelium causing larval mortality. The usage of these larvicides has been attempted in drainage canals and water bodies and shown effective results. Dead spores of the *Bacillus thuringiensis israelensis* also interfere with larval digestive systems. It can be dispersed by hand or by helicopter in the fields.

You have learnt about *Wolbachia* in Unit 10, which has been used to reduce mosquito fitness. Various fungi, such as *Metarhizium, Pseudomonas,* etc. have also been found efficacious against disease vectors. The protozoans such as *Nosema algerae* have been explored as vector control agents.

15.6 GENETIC CONTROL

Genetic control strategies aim either to suppress target population or to introduce a harm-reducing novel trait in the target vector. Different approaches differ considerably in their properties, specially between self-limiting strategies where the modification has limited persistence and self-sustaining strategies. Several methods with molecular biology are currently under development.

The Sterile Insect Technique (SIT) is a species-specific and environmentally benign method for insect population suppression, which is based on mass rearing, radiation-mediated sterilization, and release of a large number of sterile male insects. Releasing of Insects carrying a dominant lethal gene (RIDL) offers a solution to many of the drawbacks of traditional SIT that have limited application in mosquitoes while maintaining its environmentally friendly and species-specific utility. The self-limiting nature of sterile mosquitoes tends to make the issues related to the field use of these somewhat less challenging than for self-spreading system which is a characteristic of population replacement strategies. They are also closer to field use, so, that it might be appropriate to consider it.

Incompatible insect technique (IIT) has been attempted to reduce vector density in a particular geographical region. This technique involves release of a selected male population gathered from a different geographical region whose cytoplasm may be incompatible with the native population of same species. The cytoplasmic incompatibility produces sterile offspring reducing vector population. Researchers are now attempting combination of SIT and IIT and have demonstrated highly promising results.

Biocontrol through use of *Wolbachia* species is developed for controlling mosquito population and field trials are underway. You have learnt about this technique in Unit 10. The prospect of genetic control methods against mosquito vectored human diseases is rapidly becoming a reality, many decisions will need to be made on a national, regional and international level regarding the biosafety, social, cultural and ethical aspects of the use and deployment of these vector control methods.

15.7 CHEMICAL CONTROL

The judicious use of chemicals for vector control can be carried out by means as under:

- indoor residual sprays
- space spraying
- chemical larvicides and adulticides
- reduce disease transmission by shortening or interrupting vector lifespans

Vector control program in India mostly rely on usage of natural and synthetic chemical insecticides in different formulations. Wettable powder (WP) formulations are used for indoor residual sprays while emulsion concentrate (EC) formulations are used for larval control. Various groups of chemicals, such as organ chlorines, organophosphates, carbamates, synthetic pyrethroids and neonicotinoids have been tried. Synthetic pyrethroids, such as Deltamethrin, Permethrin, Cyfluthrin, Lambda-cyhalothrin and Alphacypermethrin are currently considered safest and most effective insecticides. These synthetic pyrethroids are also used for impregnation of bed nets.

The endophilic vectors are controlled by indoor IRS with insecticides having residual effect of human dwellings while exophilic vectors are effectively controlled by IRS with insecticides having good airborne effect. Other control methods, such as use of ITNs or outdoor space spraying (for emergency control) are also employed for control of strongly exophilic and/or exophagic vectors.

The chemical larvicides are best used in situations where the disease and vector surveillance indicate the existence of certain periods of high risk and in localities where outbreaks might occur as it is difficult and expensive to apply chemical larvicides on a long-term basis. Establishing the precise timing and location are essential for maximum effectiveness. Different chemicals, such as contact poisons, growth regulators, surface films, stomach poisons have been used for vector control. Growth regulators, such as diflubenzuron, is approved in India for use in potable water at a certain dosage. Adult vectors can be controlled by ground-based or aerial applications of residual chemical insecticides. Low-volume sprays, thermal fogging, and repellents are used. In India, van-mounted and hand-fogging machines are used for mosquito control.

15.7.1 Vector Resistance

The indiscriminate use of chemicals has made disease vectors resistant to them. New chemicals are being explored continuously which are effective to the target vectors but safe to non-targets and the environment.

Thus, several factors need to be considered in the selection of an insecticide spraying including availability, cost, residual effectiveness, safety, vector susceptibility and excito-repellency. The mosquito vectors such as *Anopheles culicifacies, Culex quinquefasciatus* and *Aedes aegypti* have developed resistance to frequently used chemicals. The main reasons of resistance have been considered as detoxification mechanism and target insensitivity.

Possible ways of avoiding development of insecticide resistance

There are many ways to avoid the development of insecticide resistance that are stated as under:

- Avoid indiscriminate use of insecticides.
- Avoid use of insecticides that have similar mode of action and thus, simultaneously select resistance.
- Avoid use of insecticides that induce development of more than one type of resistance mechanism in the vector.
- Avoid use of the same insecticide both against adults and larvae. Use stage-specific insecticide
- Use of non-chemical control methods, e.g. biopesticides, larvivorous fish, net screens etc.
- Use of synergist in combination with the insecticides to increase the efficacy at lower dosages and reduce physiological resistance.
- Rotate the application of different groups of insecticide with different modes of action in order to avoid resistance/cross-resistance development.

15.8 HORMONAL CONTROL

Interruption of disease transmission by the widespread use of insecticides, improved diagnosis and availability of effective drug treatment has been the mainstay of improvement in the health prospects of those living in the endemic areas. However, the control and treatment measures are under threat due to the insecticide and drug resistance, respectively. Unsurprisingly, we are witnessing a Red Queen scenario with the imposing selective pressure causing resistance to spread rapidly due to adaptive mechanisms.

The disruption of hormonal balance in disease vectors is an upcoming approach which can disrupt moulting, growth and reproduction reducing population size. Removal of brain from immature insects can cease production of brain hormone and thence moulting. In insects, ecdysteroids play an important role in the control of moulting and metamorphosis in insects. Use of hormone mimic, 20-hydroxyecdysone (20E), which plays major role in the control of egg development in mosquitoes, has been shown to inhibit the growth of developmental stages and mating receptivity in adults.

Similarly, juvenile hormone (JH) titers can be modulated to disturb the normal progress of development and reproduction in mosquitoes. Removal of corpora allata from young immature stages causes cessation of JH production leading to premature pupation and dwarf adults. The formulations, Precocene I and Precocene II are JH inhibitors which can be used for development of precocious sexually immature adults.

Methoprene is a broad-spectrum synthetic juvenile hormone mimic, which prevents larval stages from undergoing metamorphosis to viable adults. It is useful for control of mosquitoes but is only effective against larvae. Many different products and formulations containing methoprene are commercially available. Pyriproxyfen is another example of JH mimic. Several JH mimics, such as farnesol, juvocimene I and II, bakuchiol and echinolone, have been isolated from plants.

15.9 LEGISLATIVE CONTROL

The legislative measures involve laws and regulations to prevent the entry and establishment of potential foreign vectors species and to eradicate, contain or suppress those that manage to gain entrance.

Suitable laws and byelaws should be enacted and implemented for regulating storage/utilization of water by communities, various agencies and avoidance of mosquitogenic conditions at construction sites, factories.

(i) **Model civic byelaws:** Fine/punishment is imparted, if breeding is detected. These measures are being strictly enforced by Mumbai, Navi Mumbai, Chandigarh and Delhi Municipal Corporations.

(ii) **Building Construction Regulation Act:** Building byelaws should be made for appropriate overhead / underground tanks, mosquito proof buildings, designs of sunshades, porticos, etc. for not allowing stagnation of water *vis-à-vis* breeding of mosquitoes. In Mumbai, prior to any construction activity, the owners/builders deposit a fee for controlling mosquitogenic conditions at site by the Municipal Corporation.

(iii) Environmental Health Act (HIA): Suitable byelaws should be made for the proper disposal/storage of junk, discarded tins, old tyres and other debris, which can withhold rain water.

(iv) Health Impact Assessments: Appropriate legislation should be formulated for mandatory HIA prior to any development projects/major constructions.

Fig. 15.5: Legislative measures for control of disease vectors.

SAQ 2

Chose the correct option given in the parentheses.

i) Most widely used biological control agent against mosquito larvae is mosquito fish (*Gambusia*/*Labeo*).

ii) (Genetic/Chemical) control strategies aim either to suppress target population or to introduce a harm-reducing novel trait.

iii) The (endophilic/exophilic) vectors are controlled by indoor IRS with insecticides having residual effect of human dwellings .

iv) (Juvenile/Moulting) hormone titers can be modulated to disturb normal growth and development of immature insects.

v) (Methoprene/Precocene) is a broad-spectrum synthetic juvenile hormone mimic.

15.10 INTEGRATED VECTOR AND PEST MANAGEMENT (IVPM)

Excessive use of pesticides in insect and vector control has resulted in (a) disturbance in the natural balance between harmful vectors and beneficial predators in local ecosystems, (b) increased occupational exposures of community and incidence of pesticide poisoning, (c) pesticide residues in food and environment, and (d) development of insecticide resistance in disease vectors.

Realizing the ill effects of excessive dependence on chemical pesticides, the Integrated Pest Management (IPM) approach was recommended in late 19th century. It recommends the utilization of all appropriate technological and management techniques to bring about an effective degree of vector suppression in a cost-effective manner. Selection of methods is based on the detailed field information on the ecology, bionomics of vectors and their role in disease transmission.

Integrated vector and pest management (IVPM) is a rational, harmonious and decision-making process to optimize the use of resources for pest and vector control and maintain them below economic injury level. It requires a management approach that improves the efficacy, cost effectiveness, ecological soundness and sustainability of control interventions with the available tools and resources. The approach addresses several diseases simultaneously, as some measures are efficacious against various vectors while some vectors can transmit several diseases. The integrated approach can alleviate the insecticide pressure preventing the development of insecticide resistance.

IVPM encourages effective collaboration within the health sector as well as with public sectors. The empowerment of communities also carried significance. According to WHO (The World Health Organization, 2012), the Key elements of an integrated vector management (IVM) strategy are:

1. **Advocacy, social mobilization and legislation:** Promotion and embedding of IVM principles in designing policies in all relevant agencies, organizations and civil society; establishment or strengthening of regulatory and legislative controls for public health; empowerment of communities.

2. **Collaboration within the health sector and with other sectors:** Consideration of all options for collaboration within and between public and private sectors; application of the principles of subsidiarity in planning and decision-making; strengthening channels of communication among policy-makers, vector-borne disease programme managers and other IVM partners.

3. **Integrated approach:** Ensure rational use of available resources by addressing several diseases, integrating non-chemical and chemical vector control methods and integrating with other disease control methods.

4. **Evidence-based decision-making:** Adaptation of strategies and interventions to local ecology, epidemiology and resources, guided by operational research and subject to routine monitoring and evaluation.

5. **Capacity-building:** Provision of the essential material infrastructure, financial resources and human resources at national and local level to manage IVM strategies on the basis of a situational analysis.

15.10.1 Farmer Field School Approach

Over the years, IPM led to the development of the Farmer Field School (FFS) movement. FFS is a modern, participatory learning and community empowering approach based on season-long practical demonstration of improved farming practices to protect the farming community and the agro-ecosystems from the ill effects of pesticide use, thereby aiming to create sustainable agriculture and environment. The FFSs, comprising groups of 15-30 farmers, are facilitated by agricultural extension trainer, to learn conduct agro ecosystem analysis, identify agricultural pests and beneficial predators, and make informed decisions about crop management and use of pesticides. The IPM FFS approach was applied in rice cultivation in the mid-1990s in Asia and later expanded to vegetables, cotton and various other crops in other regions. A wide range of benefits of IPM FFS, including development impacts, have been reported. India has a large IPM programme, including the rice IPM.

IPVM strategy has helped farmers to reduce health risks associated with vector-borne diseases and pesticides. The Malaria Control Programme plans to adopt the integrated pest and vector management strategy to prevent malaria in areas of low transmission since there is an additive effect between the use of mosquito nets and the strategy.

15.10.2 Anticipated Roles of Various Sectors in IVM Implementation

Various sectors can come together to play important roles in IVPM approach. In Agriculture, there is a need to popularize the concept of dry-wet irrigation through extension education and pesticide management. In Water resources development, there is a necessity for maintenance of canal system, intermittent irrigation, design modifications and lining of canals; weeding for proper flow; creating small check-dams away from human settlements; health impact assessment (HIA) etc. In Water supply, there is a constant need to repair leakages to prevent pooling, restoration of taps, diversion of wastewater to pond/pit, staggering of water supply, mosquito-proofing of water harvesting devices, repair of sluice valves, etc.

Road and building sector requires proper planning as per by-laws, merging pits by breaking bunds, excavations in line with natural slope/gradient, making way for water to flow into natural depression/pond/river, follow-up actions after excavations. Urban development needs implementation of building by-laws, improved designing to avoid undue water lodging and building use permission after clearance of health department. Industry/mining has to regularly monitor to improve drainage/sewerage system, safe disposal of solid waste/used containers, mosquito-proofing of dwellings, safe water storage/disposal and use of ITN/LLIN. Railways have to carry out proper excavations, maintenance of yards and dumps and conducting anti-larval activities within their jurisdiction.

To keep Environment/Forest in healthy state, pesticide management policies, environment management policies, reclamation of swampy areas, social forestry are the mainstay. Fisheries Institutions can help in mass production of larvivorous fishes. Promotion of composite fish farming schemes at community level is must to keep the vector of the diseases at bay. Remote sensing (GIS) technical/training help in mapping environmental changes and disease risk must be undertaken for the needful. Private pest control agencies must take care of judicious use of insecticides, promotion of IVM-based sustainable preventive and control methods.

SAQ 3

Match the following:

Column 'A'	Column 'B'
i) IVPM	a) Modern participatory learning and community empowering
ii) FFS	b) Provision of the essential infrastructure and resources
iii) Capacity building	c) Producing larvivorous fishes
iv) Fisheries Institution	d) Rational, harmonious and decision-making process

15.11 SUMMARY

Let us summarise what we have learnt so far:

- IVM is a rational decision-making process for the optimal use of resources for integrated vector management (IVM).
- The main aim of the IVM is to contribute to achieve the global targets set for vector-borne disease control, by making vector control more efficient, cost effective, ecologically sound and sustainable.
- Environmental methods of controlling mosquito breeding include source reduction methods, *i.e.,* reduction of their breeding sites by filling ditches, pits, low lying areas, streamlining, canalizing, desilting, de-weeding, trimming of drains, water disposal and sanitation, emptying water containers.
- Mechanical measures include the direct or indirect methods that control the vectors by making environment unsuitable for their entry, dispersal, survival or reproduction.
- Biological control of vectors employs natural enemies or competitors either by introducing new species into the vector habitat or by increasing the effectiveness/density of those already present; such as *Gambusia affinis,* immature stages (naiads) of mayflies and dragonflies, mermithid worms, (*Romanomermis culicivorax*), copepods, notonectid bug. Lizards, gecko, etc.
- Disease-causing microorganisms; bacteria, virus, fungi and protozoans; are used to control pests and vectors. Examples are *Bacillus sphaericus, Bacillus thuringiensis israelensis, Wolbachia, Metarhizium, Pseudomonas, Nosema algerae,* etc.
- Genetic control strategies, such a SIT and IIT, aim either to suppress target population or to introduce a harm-reducing novel trait in the target vector.

- The judicious use of chemicals for vector control can be carried out by indoor residual sprays, space spraying, chemical larvicides and adulticides to reduce disease transmission by shortening or interrupting vector life spans.
- The indiscriminate use of chemicals has made disease vectors resistant to them. We should avoid indiscriminate use of insecticides, those that have similar mode of action and that induce development of more than one type of resistance mechanism in the vector.
- The disruption of hormonal balance in disease vectors is an upcoming approach which can disrupt moulting, growth and reproduction reducing population size.
- The legislative measures involve laws and regulations to prevent the entry and establishment of potential foreign vectors species and to eradicate, contain or suppress those that manage to gain entrance.
- Integrated vector and pest management (IVPM) is a logical and harmonious process to optimize the use of resources for pest and vector control and maintain them below economic injury level.
- The approach seeks to improve the efficacy, cost-effectiveness, ecological soundness and sustainability of disease-vector control.

15.12 TERMINAL QUESTIONS

1. Explain the concept of Integrated Vector Management.
2. Discuss the mechanical methods of Vector Control.
3. Describe the biological control method of Vector Management.
4. How can the disease vectors be genetically manipulated to reduce their population?
5. Why have insects vectors developed resistance to insecticides?

15.13 ANSWERS

Self Assessment Questions

1. i) elimination, ii) concrete, iii) drainage, iv) impervious, v) low, vi) low.
2. i) *Gambusia*, ii) Genetic, iii) endophilic, iv) Juvenile, v) Methoprene.
3. i) d, ii) a, iii) b, iv) c.

Terminal Questions

1. Refer to Section 15.2.
2. Refer to Section 15.4.

3. Refer to Section 15.5.

4. Refer to Section 15.6.

5. Refer to Sub-section 15.7.1.

Acknowledgement of Figures

Fig. 13.5: https://en.wikipedia.org/wiki/Leishmania_donovani

Fig. 14.1: https://www.flickr.com/photos/sharman/6331634

Fig. 14.2: https://en.wikipedia.org/wiki/File:Housefly_maggots_feeding_on_manure.jpg

GLOSSARY

Acaricide : Chemical that kills mites and ticks. Most acaricides are also insecticides.

Aestivation : Condition in which an organism has a period of inactivity as an adaptive response to unfavourable conditions encountered during the summer, or in the tropics the hot or dry seasons, e.g. aestivating adults of some *Anopheles* species.

Amastigote : Morphological form of species of *Leishmania* and *Trypanosoma* with a rounded body and without a flagellum that occurs predominantly in macrophages (*Leishmania* species) or muscle cells (*T. cruzi*) of a vertebrate host.

Anthropophagic (anthropophilic) : Refers to blood-sucking arthropods that prefer to feed on humans rather than other hosts. The degree of anthropophagy can very geographically within species as well as between species.

Biodegradable insecticide : Insecticide that does not accumulate in the environment but is broken down by microorganisms in the soil and water into relatively harmless compounds, e.g. the organophosphates and carbamates.

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

Chemosterillant : Chemical used to induce sterility, but not usually death, in arthropods so as to control them, e.g. apholate and tepa. Chemosterilized insects are sometimes used in genetic control of insect vectors.

Chitin : A constituent of arthropod regulators (IGRs) prevent chitin formation and are used in the control of vectors.

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

Diapause : State of inactivity or arrested development which allows an organism to survive a period of unfavourable conditions. Development cannot be resumed, even under favourable conditions, until diapauses is ‘broken’ by environmental stimuli such as changes in photoperiod (length of daylight) or temperature.

Diurnal : Refers to activity during the daylight hours, such as blood-feeding in simuliids and appearance in peripheral vertebrate blood of microfilariae of some helminth speices, e.g. *Loa loa*.

Emulsion	:	Suspension of minuscule droplets of one liquid in another. For example, when an insecticide dissolved in oil is mixed with water this results in a milky emulsion.
Endophagic	:	Describes insects, such as some mosquitoes, that enter houses to blood-feed.
Endophilic	:	Describes insects, such as some mosquitoes, that rest in houses before or after blood-feeding in houses or outside.
Epmastigote (crithidial form)	:	Morphological form of a trypanosome with the flagellum emerging about halfway in the body but remaining attached to mid-gut of triatomine bugs. This is not the stage that is infective to the vertebrate host.
Exophilic	:	Term applied to insects that blood-feed outside houses, e.g. *Aedes aegypti* and simuliid species.
Exoskeleton	:	Outer body layer, often called the integument or cuticle, of arthropods that is shed during moulting from one life-stage to another, e.g. third-instar mosquito larva to fourth-instar, and then fourth-instar larva to pupa.
Exuvia	:	The cast-off skin (exoskeleton) of a larval stage or pupa as an arthropod progresses to the next developmental stage. Often referred to in the plural as exuviae.
Haemocoel	:	Main body cavity of arthropods in which insect blood (haemolymph) circulates.
Haemolymph	:	Insect blood, usually colourless and clear, which fills the haemocoel.
Hemimetabolous (incomplete metamorphosis)	:	Describes the development from egg to adult which is gradual, passing through one or more nymphal stages, e.g. lice and ticks. If adults are winged the nymphal wing buds grow lager at each moult, e.g. bedbugs. There is no pupal stage.
Hibernation	:	Period of inactivity and/or altered behavior caused by cold conditions, e.g. winter. Some mosquitoes, e.g. *Cules pipines* in Europe, may remain in complete hibernation without blood-feeding for many months by living off their fat reserves. Other species, e.g. *Anopheles atroparvus,* enter incomplete hibernation, during which time adults need to emerge periodically from hibernation sites to take blood-meals to renew their fat reserves.

Holometabolous (complete metamorphosis)	:	Arthropod development from egg to adult in which the body form changes completely in appearance. A pupal or puparial stage is characteristic of holometabolous development.
Horizontal transmission	:	Transfer of an infectious agent from n individual to another, excluding the process of transvarial and transstadial transmission.
Insect growth regulator (IGR)	:	Sometimes known as insect development inhibitors, IGRs are groups of chemicals that either prevent the development of larvae into pupae or pupae into adults (juvenile hormone analogues, e.g. methoprene) or interfere with the moulting process, killing larvae as they moult (chitin synthesis inhibitors, e.g. diflubenzuron).
Instar	:	One of a series of life-cycle stages in metamorphosis that are separated by a moult, e.g. the first, second and third larval instars of house flies and the five nymphal stages of bedbugs.
Intermediate host	:	Host in which a parasite does not reach sexual parasites in mosquitoes and simuliids.
Intrinsic incubation period	:	Duration of the life cycle of a parasite in the vertebrate host; interval between infection and first clinical symptoms.
Larviparous	:	Reproduction in which the egg(s) hatch within the female and larva(e) are deposited, e.g. tsetse flies.
Maggot	:	Legless larva that has no distinct head, thorax or abdomen, e.g. larvae of house flies.
Metamorphosis	:	Changes in form from first stage (egg) in the life cycle of an arthropod to the adult form. In hemimetabolous arthropods, e.g. bedbugs, lice, ticks and mites, the change is gradual through nymphal stages which resemble small versions of the adult. In holometabolous arthropods, e.g. mosquitoes, tsetse flies and fleas, the changes are abrupt and involve larval stage(s) and a pupal or puparial stage which are very dissimilar to the adult.
Microbial insecticide	:	Insecticide comprising a biological agent such as bacteria, e.g. *Bacillus thuringiensis* var. *israelensis* and *B. sphaericus,* or toxic compounds derived from such agents.
Moulting (also spelt molting)	:	Process of shedding the cuticle between developmental stages (i.e. instars).

Myiasis	:	Invasion of vertebrae organs or tissues by larvae of Diptera that feed on living or dead tissues. Myiasis may be accidental, obligatory or facultative. Accidental myiasis usually involves people eating food contaminated with fly eggs or larvae; no real harm is caused; live larvae may be passed in excreta or vomit.
Nicotinoids	:	The nicotinoids such as imidacloprid and dinotefuran are a relatively new class of insecticides. They are related to nicotine, which has been used mainly as an agricultural insecticide. They act on the acethylcholine system, and are safe on mammals but kill a broad range of insect pests.
Nit	:	Egg of louse, such as a head louse.
Nymph	:	In incomplete metamorphosis (hemimetabolous development) the stage in the life cycle that hatches from the egg (e.g. bedbugs, lice), or the stage that arises through the moulting of the larval stage (e.g. ticks).
Oocyst rate	:	Percentage of mosquitoes that have malarial oocysts one the stomach.
Organochlorines (chlorinated hydrocarbons)	:	Synthetic insecticides containing carbon, chlorine and hydrogen, e.g. DDT, dieldrin, HCH and methoxychlor.
Organophosphates	:	Synthetic insecticides which are derivatives of phosphoric acid and hence all contain phosphorus, e.g. diazinon, dichlorvos and malathion.
Pheromone	:	Chemical (semiochemical) released usually as an odour by an individual which produces reactions in others of the same species, e.g. sex pheromones in tsetse flies and ticks.
Phyrethroids	:	A large group of synthetic insecticides structured to be similar to natural pyrethrum but which are more effective. Examples are permethrin, deltamethrin, and cypermethrin.
Promastigote (leptomonad)	:	Morphological form of a trypanosomatid with the flagellum arising near the anterior end, e.g. *Leishmania* parasites in the phlebotomine sand fly gut.
Sclerotization	:	Process which results in the new arthropod cuticle formed after moulting being tanned (darkened) and hardened to give it rigidity.
Sex pheromone	:	A chemical compound by a species that attracts members of the opposite sex of the same species. Such chemicals can be used to lure species to traps so that they can be killed.

Sporozoite rate	:	Percentage of mosquitoes with malarial sporozoites their salivary glands.
Sterile male release (sterile-insect technique, SIT)	:	In genetic control programmes the inundative release of large numbers of artificially sterilized male arthropods into field populations in the hope that this will result in sterile matings and consequently a reduction in population size.
Sylvatic	:	In epidemiology means that diseases are contracted in woods or forests, e.g. the forest cycle of yellow fever.
Synanthropic	:	Applied to animals living in close association with humans or their houses, e.g. house flies and triatomine bugs.
Transovarial transmission	:	Production by an infected vector of eggs infected with parasites (e.g. viruses, rickettsiae). When they hatch they give rise to individuals (e.g. larvae, nymphs) that are infected and are either capable of transmitting the parasites (e.g. ticks) or passing it on to later life-cycle stages that transmit the infection (e.g. scrub typhus mites).
Ultra-low-volume (ULV)	:	Refers to spraying an insecticide in concentrated form; thus the dosage rate is small, e.g. 5 liters/hectare.
Vector	:	Organism that conveys and aetiological agent from one host to another. A vector may be an intermediate host (e.g. culicines transmitting filariasis) or not (e.g. house flies mechanically transmitting bacteria).
Viraemia	:	Presence of virus in vertebrate blood. High viraemias are usually necessary for transmission by arthropod vectors.
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 surfaces.
Zoonosis	:	An infection that is naturally transmitted between vertebrae hosts and humans.

APPENDIX

Names of Some Chemicals and Microbials used in Vector Control (with common trade names in parentheses)

Carbamates

Bendiocarb (Ficam)

Carbaryl (Sevin)

Propoxur (Arprocarb, Baygon)

Formamidines

Amitraz (Mitaban)

Chlordimeform (Fundal, Galecron)

Inorganics

Borax

Insect growth regulators (IGRs)

Cyromazine (Larvadex)

Diflubenzuron (Dimilin)

Fenoxycarb (Insegar, Logic)

Flufenoxuron (Cascade)

Hydroprene (Protrol)

Kinoprene (Enstar)

Lufenuron (Sentinel)

Methoprene (Altosid)

Novaluron (Rimon)

Noviflumuron

Pyriproxyfen (Cyclio, Nylar)

Triflumuron

Microbials

Bacillus sphaericus (Vectolex)

Bacillus thuringiensis var. *israelensis* (*Bti*) (= *Bacillus thringiensis* H-14) (Aquabac, Teknar, Vectobac)

Spinosad (fermentation of an actinomycete bacterium, *Saccharopolyspora spinosa*)

Monomolecular films

Isosteasryl alcohols (Arosurf MSF, Agnique MMF)

Lecithins

Natural organics

Neem oil

Petroleum oils

Pyrethrum

Nicotinoids

Dinotefuran

Imidacloprid

Organochlorines

DDT, i.e. dichlorodiphenyltrichloroethance

Endosulfan

HCH, i.e. hexachlorocyclohexane (formerly BHC)

Lindane

Methoxychlor (Chemform, Methodox)

Toxaphene (Camphechlor)

Organophosphates

Azamethiphos

Bromophos

Chlorpyrifos (Dursban)

Coumaphos (Muscatox)

Diazinon

Dimethoate

Dioxathion (Hercules)

Fenchlorphos (Fenchlorvos, Ronnel)

Fenitrothion (Nuvanol, Sumithion)

Fenthion (Baytex)

Malathion (Carbophosm)

Naled (Dibrom)

Phoxim

Pirimiphos-methyl (Actellic)

Temephos (Abate)

Trichlorton (Dipterex)

Pheromones

Muscalure

Phenylpyrazoles

Fiprinol (Frontline, Top Spot, Termidore)

Pyrethroids

Allethrin (Bioallethrin, Pynamin)

Alpha-cypermethrin

Betacyfluthrin

Bifenthrin (Brigade, Talstar)

Cyfluthrin (Baythroid)

Cyhalothrin (Karate, Kung Fu)

Cypermethrin (Cymbush)

Cyphenothrin (Arrivo, Ripcord)

Deltamethrin (K-Othrin, Decis)

Esfenvalerate

Etofenprox

Fenvalerate (Bhasma, Tribute)

Lambda-cyhalothrin (Icon)

Permethrin (Ambush)

Phenothrin (Sumithrin)

Resmethrin (Bioresmethrin)

Tetramethrin

Pyrroles

Chlorfenapyr (Pirate, Pylon Miticide)

Repellents

Autan (Cutter Advanced) – a picaridin-based compound

Bayrepel (KBR 3023) – a picaridin-based compound

Benzyl benzoate (Ascabiol)

Citronella oil

DEET, i.e. diethyl-3-methylbenzamide (formerly called diethyl-meta-tuluamide)

Dibutyl phthalate

Dimethyl carbamate

Lemon eucalyptus oil

PMD – a botanical comound (para-menthane-3, 8-diol) derived from lemon eucalyptus

Sulphonamides

Sulfluramid

Synergists

Piperonyl butoxide

ANNEXURE I: SANDFLIES AS VECTORS OF DISEASES

Diseases	Vectors	Animal hosts	Distribution
Cutaneous leishmaniasis (severe dermal lesions)	*Phlebotomus* spp. (Old World) *Lutzomyia* spp. (New World)	Disease reservoirs are rodents and other mammals	Widely distributed in Central Asia, the Indian subcontinent, Eastern Mediterranean, Middle East, Southern Africa and parts of Ethiopian Region, and Central and Southern America. Epidemics may occur where displaced populations are forced to live outdoors in proximity to rodent colonies or wild animals.
Visceral leishmaniasis (kala azar) (fatal if not treated)	*Phlebotomus* spp. e.g. *P.orientalis* (Old World) *Lutzomyia* spp. (New World)	Disease reservoirs are dogs, wild canines and humans	Occurs in Central Asia, India, South America, the Mediterranean basin, Sudan and East Africa. Epidemics are associated with war and famine
Sandfly fever (mild infection)	*Phlebotomus* spp. (Old World)		Mediterranean basin, Near and Middle East, Central Asia and South China

ANNEXURE II: GENERALISED BIOLOGICAL INFORMATION ON INSECT VECTORS THAT AFFECT THE FEASIBILITY OF CONTROL

Insect vectors	Vector species	Disease	Breeding sites	Resting sites	Transmission	Blood source	Dispersal range	Control feasibility
Mosquitoes	*Anopheles*	Malaria; filariasis; arboviruses	Swamps, still water, containers	Indoors/ outdoors	Night	People and animals	2 k	Can be very effective – need specialist advice
	Aedes	Encephalitis; filariasis	Containers, small pools of stagnant water	Indoors/ outdoors	Day	People and animals	0.1 – 0.8 km	Can be very effective – need specialist advice
	Culex	Filariasis; encephalitis	Organically polluted water	Indoors/ outdoors	Day and night	People and animals	0.1 – 0.8 km	Can be very effective – need specialist advice
Lice	*Pediculus*	Typhus; relapsing fever; trench fever	Clothing on human body or that has been worn within the last two weeks	Clothing on human body	Day and night	People only	n/a	Very effective and simple
Filth flies	*Musca*	Eye disease; diarrhoeal disease	Organic matter, faeces, food, corpses	Indoors/ outdoors	Day	n/a	5 km	Sanitation very important
Tsetse-flies	*Glossina*	Sleeping sickness	Soil	Tree trunks	Day	People and animals	2 – 4 km	Need specialist advice
Sandflies	*Phelbotomus Lutzomia*	Sandfly fever; leishmaniasis	Mud cracks, termite hills, animal burrows, mud walls	Indoors/ outdoors	Night	People and animals	600 m	Need specialist advice
Blackflies	*Simulium*	River blindness	Fast-flowing rivers	Outdoors	Day	People and animals	10 km	Need specialist advice

Ticks/mites	*Ixodidae Trom-buciliidae*	Typhus	Vegetation	Outdoors	Day	People and animals	n/a	Destroy vegetation
Cone-nosed bugs	*Reduviidae*	Chagas disease	Cracks in walls and furniture	Indoors	Night	People and animals	10-20 m	Insecticide control simple
Fleas	*Xenopsylla*	Plague; murine typhus	rats	With rats	Night and day	People and animals	n/a	Treat rat burrows with insecticide before controlling rats

A: Mites as vectors of diseases.

Vector	Disease	Distribution
Sarcoptes scabiei	Scabies	Worldwide
Trombiculid mite	Scrub typhus *Rickettsia tsutsugamushi*	Restricted to Asia e.g. West Pakistan, Japan, Tropical Queensland, Pacific islands
	Nuisance bites by the larvae (çhiggers') cause intense itching	Tropical and temperate regions of the world

B: Ticks as vectors of diseases.

Vectors	Diseases	Distribution
Soft tick (*Ornithodoros moubata*) whose lifestyle is similar to that of the bedbug	Only important human disease is endemic relapsing fever (*Borrelia duttoni*)	Throughout most of the tropics and subtropics, as well as North America and Southern Europe
Hard ticks (*Ixodides* spp.)	Tick paralysis resulting from toxins in tick saliva	Throughout the world but rare
	Spirochaetal infections such as Lyme disease (*Borrelia burgdorferi*)	Europe and North America where it has recently caused an epidemic of arthritis
	Rickettsial infections (such as Rocky Mountain Fever *R. rickettsia*)	North America
	Viral infections such as Russian spring-summer encephalitis	Widespread in Far East especially USSR