Review

Diptera: the order of great public health nuisance

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Dipterans are insects with only one pair of functional wings, the hind wings are reduced to a pair of stalked knobs, called the ‘halteres’, which are used for balance during flight. Most members have their mouthparts, modified for piercing and sucking. All dipterans undergo holometabolous life cycle. Dipteran families of medical significance include: family Simuliidae (Black-flies that spread the disease, Onchocerciasis), family Psychodidae (Sandflies that spread Leishmaniasis), family Culicidae, (Mosquitoes that spread Malaria, Yellow fever, Dengue fever, Encephalitis and Filariasis), family Tabanidae (Horseflies and Deer flies that spread Loiasis), family Chloropidae (Eye gnats that spread eye yaws and conjunctivitis), family Glossinidae (Tse-tse flies that spread Trypanosomiasis), families Muscidae, Calliphoridae and Sarcophagidae (House flies, Blow Flies and Flesh flies that spread Dysentary, Typhoid fever, Cholera and Poliomyelitis). These diseases are transmitted either mechanically or biologically. Dipterans are controlled either at immature (larval and pupal) or at mature (Adult) stages. These control measures include: Biological, Genetical, Physical or Chemical control methods. Although dipterans are insects of great public health nuisance, their roles as scavengers/decomposers in both terrestrial and aquatic environments cannot be neglected. While the above mentioned control measures should be employed against dipterans of medical importance, the scavengers should be harnessed under strict control for waste management, in order to have cleaner and safer environment in our ever increasing population.

Keywords: Dipters, Human Diseases, Control, Public Health Nuisance, Waste Management.

INTRODUCTION

Dipterans are among the most ubiquitous and widely distributed insects with 128 families and about 124,000 described species (Brown, 2001). Their close association with humans has led them to be perceived as annoying and unpleasant creatures. Indeed some flies are the cause of millions of deaths and illnesses (Malaria, Trypanosomiasis, Dysentary, Diarrhoea, Typhoid Fever, Filariasis, etc), among human populations. Yet flies are also among the key components in most ecosystems and are beneficial in many ways.

What are flies?

Brown (2001) defined Flies/Dipterans as insects with only one pair of functional wings; the hind wings are reduced to a pair of stalked knobs, called ‘halteres’, which are used for balance during flight. In most members, the adult mouthparts are modified for sucking liquids. Mandibles used in most insects for chewing are usually absent. When these mandibles are present in insects like mosquitoes, they are in form of slender stylets, that can
pierce the skin of larger animals. All members of the order Diptera undergo a holometabolous life cycle. Larvae of many flies such as Mosquitoes and Blackflies are aquatic; other dipterous larvae live in semi-aquatic habitats like muddy ground or in very humid situations such as in decaying vegetable matter, soil, animal excreta or festering wounds and sores. Larvae of a few species are wholly or partially parasitic in tissues of man or animals and cause a condition, known as ‘Myiasis’ (Vincent and Carde, 2009).

Classification/Members of medical importance

The dipterans are divided into three sub-orders:

The Sub-Order Nematocera

This sub-order houses the most primitive dipterans which comprises of mainly small flies with simple type of many-segmented antennae. Families of Medical Importance, belonging to the sub-order Nematocera include:

- Family Culicidae e.g. Mosquitoes
- Family Psychodidae e.g. Sand flies
- Family Simuliidae e.g. Black flies
- Family Cerapogonidae e.g. Biting Midges (Blagoderov et.al, 2001; Michelson 1996).

Sub-Order Brachycera

This sub-order includes mainly large flies, having the antennae generally divided into 3 segments. The medically important species in the sub-order Brachycera belong to the Family Tabanidae, in which the antennae are short and stout in many genera. Examples include: *Tabanus, Chrysops* species (Blagoderov et.al, 2002; Michelson, 1996).

Sub-Order Cyclorrhapha

The antennae of members of this suborder also consist of three segments, but the last one always bears a bristle, called the ‘Arista’. Insects in this sub-order include those that are generally called ‘flies’ of the non-specialists, such as: Houseflies, Blowflies and Tse-tse flies. Families belonging to the sub-order Cyclorrhapha include:

- Family Muscidae e.g. Houseflies
- Family Glossinidae e.g. Tse-tse flies
- Family Calliphoridae e.g. Blowflies
- Family Oestridae e.g. Warble flies (Blagoderov et.al, 2002; Michelson, 1996).

Families of medical importance/significance

Family Simuliidae

These include Blackflies which spread ‘*Onchocerca volvulus*’, a parasitic roundworm. Onchocerciasis, the disease condition caused by infestation of these worms may cause blindness in people of Africa, Mexico and Central and South America (Gatz, 1996).

Family Psychodidae

These include Sandflies in the genus *Phlebotomus*. They are vectors of a bacterium, *Bartonella bacilliformis* that causes carrion’s disease (Oroyo fever) in South America. In parts of Asia and Africa, they spread a viral agent that causes sandfly-fever (Pappataci fever) as well as protozoan pathogens (*Leishmania* species) that cause Leishmaniasis (Gatz, 1999).

Family Ceratopogonidae

Members of this family are commonly called the ‘Punkies’. They are vectors of parasitic roundworms in several genera e.g. *Onchocerca, Mansonella* (etc) (Gatz, 1996).

Family Culicidae

This includes the Mosquitoes. Mosquitoes in the genus *Anopheles* are the principal vectors of malaria, a life threatening infection, caused by a protozoan in the genus *Plasmodium*, *Aedes aegypti* is the main vector of the viruses that cause Yellow fever and Dengue fever. Other viruses that cause Encephalitis are also carried by Mosquitoes of *Aedes* species, *Wuchereria bancrofti* and *Brugia malayi* are parasitic roundworms that cause Filariasis, which are usually spread by Mosquitoes in the genera, *Culex, Mansonia* and *Anopheles*. (Gatz, 1996; Chamberlation and Sudia, 1961).

Family Tabanidae

Members here are Horseflies and Deerflies, which transmit bacterial pathogens of tularemia; *Pasteurella tularensis* and anthrax (*Bacillus anthracis*), as well as parasitic roundworms, *Loa loa* that causes ‘loasis’ in tropical Africa (Gatz, 1996).

Family Chloropidae

These are the eye gnats in the genus *Hipelates* that can
carry the spirochaete pathogens that cause yaws (*Treponema Pertenuis*) and may also spread conjunctivitis (the pink eye) (Gatz, 1996).

**Families’ Muscidae, Calliphoridae and Sarcophagidae**

These include the Houseflies (family Muscidae), Blow flies (family Calliphagidae) and flesh flies (family Sarcophagidae). They often live among filth and garbage. They carry the pathogens for dysentary (*Shigella dysentariae*), Typhoid fever (*Salmonella typhi*) and cholera (*Vibrio cholerae*) on their hairy bodies, feet and mouthparts and transfer such on food or wounds of humans (Mechanical transmission). They have also been suspected as vectors of the viral agent that causes poliomyelitis (Gatz, 1996).

**Family Glossinidae**

These are the Tse-tse flies in the genus *Glossina*. They transmit the protozoan pathogens that cause African sleeping sickness (*Trypanosoma brucei gambiense* and *T. b. rhodensiense*). (Leak, 1998).

**Modes of disease transmission by dipterans**

Dipterans transmit diseases by 2 major methods: mechanical and biological transmission (Gullan and Cranston, 2005).

**Mechanical transmission method**

Flies transmit human diseases mechanically. In this method, the disease pathogens undergo no developmental stages in the insects. These flies may be blood suckers or non-blood suckers. Mechanical transmission method is further divided into 2: Direct Mechanical and Indirect Mechanical Transmission Methods (Graczyk *et. al.*, 2005; Thaddeus *et. al.*, 2005).

Direct Mechanical disease transmitters are blood suckers (*e.g.*) Tse-tse flies, Sand flies, etc. They pick up germs (parasites) from the bodies of diseased individuals during their blood meal and inoculate them directly into the skin sores and wounds. They function as active carriers of parasites. Some diseases transmitted by direct mechanical method include Trypanosomiasis, Eye yaws, Leishmaniasis (etc).

Indirect mechanical disease transmitters carry on their hairy legs and bodies, numerous pathogenic organisms such as viruses, bacteria, protozoans and even helminth eggs, which they pick up from excreta, pus, wounds (etc) and they deposit them on man’s food. Man then gets infected when he ingests the food infested with these disease agents.

Some diseases spread in this way include: Typhoid fever, diarrhoea, dysentery, cholera, tuberculosis (etc) (Graczyk *et. al.*, 2001; Tan *et. al.*, 1997).

**Biological transmission method**

In this method of disease transmission, the disease pathogens undergo certain developmental stages in the dipteran vectors which are exclusively blood suckers. Biological development can take place propagatively, cyclopropagatively and cyclodevelopmentally or cyclically. Thus, we have 3 types of biological transmission methods.

Propagative biological transmission

Cyclopropagative biological transmission

Cyclodevelopmental biological transmission. (Service, 1997)

In Propagative biological transmission method, the disease agents (parasites) multiply as in culture tubes inside the dipteran hosts. They do not change forms. Viruses undergo this type of development in both dipteran vectors and the animal hosts and are said to be transmitted Propagatively. Examples of diseases transmitted this way include: yellow fever and plague and are transmitted by Mosquitoes.

In Cyclopropagative transmission method, parasites undergo structural changes and also multiply in the process. Protozoans undergo cyclopropagative development, thus Malaria, transmitted by Mosquitoes and Trypanosomiasis, transmitted by Tse-tse flies are examples of human disease transmitted Cyclopropagatively.

In cyclodevelopmental or cyclical transmission, the disease agents undergo developmental changes in forms but do not multiply. Dracunculiasis (Guinea worm disease) and Filariasis are examples of diseases transmitted Cyclodevelopmentally.

Biological disease transmission mode can be stated concisely as “Innoculation by salivation”. Disease pathogens are picked from infected and transmitted to healthy individuals by blood-sucking Dipterans; mainly the females, as they require blood meals for the maturation of their eggs. When the fly bites an infected individual, it becomes infected itself and if it bites a healthy individual, it infects/innoculates the parasites into his blood with the saliva, containing anti-coagulant, which is injected before sucking up blood to prevent its coagulation or clotting (Service 1997).

**Flies as vectors of human diseases**

Since time immemorial, flies have been the constant companions of humans and due to the tendency of some
species to feed on humans and pass on pathogens that cause diseases, they have been notorious as vectors of human and animal diseases. (Harrison, 1978, Bruce-Chiwatt, 1988). Human diseases caused by flies have their largest impact in tropical areas, although they were more widespread in the past (De zuluetta, 1994).

Vector-borne diseases require an interaction between the fly, pathogen, host (e.g.) humans and the environment. It can also be complicated by reservoir hosts.

Non-biting flies can transmit fly-borne pathogens mechanically (e.g.) Houseflies spread intestinal pathogens, causing Typhoid (Graczyk et al., 2001) and biting flies can transfer pathogens biologically where the main natural route for the pathogen is through the fly; (e.g.) Malaria parasite undergoes part of its life cycle in the fly. The mouthparts of these dipteran vectors are modified for piercing, blood sucking and lapping. They also have highly developed mechanisms for vertebrate host location (Gibson and Torr, 1999).

Dipterans of great medical importance that will be discussed here include: Mosquitoes, Houseflies, Sandflies, Blackflies, Tse-tse flies and Horseflies.

**Mosquitoes**

These are vectors that carry disease-causing viruses and parasites from persons to persons and also from animals to persons. The principal mosquito borne diseases include: Malaria, Yellow fever, Dengue-fever, Filariasis and Encephalitis (Tolle, 2009).

**Malaria**

This is a mosquito-borne infectious disease of humans and other animals, caused by eukaryotic protists of the genus *Plasmodium* and transmitted by the female *Anopheles* mosquitoes. The protists first infect the liver and then the red blood cells, causing symptoms like fever, headache and in severe cases, progressing to coma or death. The disease is widespread in tropical and subtropical regions, mostly sub-Saharan Africa and Asia. Malaria is prevalent in these areas due to significant amounts of rainfall, consistent high temperature, high humidity and availability of stagnant water in which mosquitoes breed. The World Health Organization has estimated that in 2010, there were 216 million cases of malaria and about 655,000 people died from the disease, most of whom were children under the age of 5 (WHO, 2011). Disease transmission can be reduced by preventing mosquito bites through the following ways – use of mosquito nets, use of insect repellent creams, spraying insecticides, indoors and draining standing/ stagnant waters. Efforts to develop vaccines are still ongoing. Chemoprophylactic drugs are also available to prevent malaria especially in travelers to malaria-endemic countries. A variety of anti-malarial medications are available for the treatment of malaria. WHO recommends the effective treatment of malaria with Artemisinin Combination Therapy (ACT) due to development of resistance to several anti-malarial drugs, especially chloroquine (WHO, 2011).

**Yellow fever**

This is a fatal viral infection transmitted by *Aedes aegypti* mosquitoes in tropical regions. A classic feature of yellow fever is hepatitis, which is the reason for the yellow colouring of the eye (jaundice). Other symptoms include: fever, intestinal bleeding, kidney failure and meningitis (Barrett and Higgs, 2007). The virus is introduced into the blood stream through the saliva of an infected mosquito as it bites. The virus can then be transported around the body and can reproduce itself in a variety of the body’s cells, usually, the liver, kidneys and blood vessels, destroying the cells. The cells of the immune system are also affected and they release large quantities of signaling substances. These substances cause the disease symptoms, (e.g.) muscular pains, fever, (etc). Yellow fever can cause sudden epidemics with a mortality rate of almost 50%. A safe and efficient vaccine against yellow fever has been available in the last 60 years (Barret and Teuwen, 2009).

**Dengue fever**

Dengue fever is a viral infectious disease transmitted by the mosquitoes (*Aedes aegypti*) and caused by any of the four dengue viruses (DEN 1, DEN 2, DEN 3 and DEN 4) (Sabin, 1955). The disease was called “break bone” fever because it causes severe joint and muscle pain that feels like bones are breaking. Dengue fever is found mostly during and shortly after the rainy season in tropical and subtropical areas of Caribbean, Central and South America, Africa, South East Asia and China, India, the middle East, Australia and the South and Central Pacific.

The symptoms include: high fever (up to 105° F) (Sabin, 1955). Headache, retro-orbital (behind the eye) pain, severe joint and muscle pain, nausea, vomiting and rash. There is no specific treatment for dengue fever, most people recover within 2 weeks. Aggressive emergency treatment with fluid and electrolyte replacement can be helpful. Dengue fever can be prevented by:

- Keeping surrounding areas free from standing water.
- Use of insect repellent creams when outside.
- Use of window, door and bed nets.
Lymphatic filariasis (elephantiasis)

This is an infectious parasitic disease mostly seen in the tropical regions. It is caused by thread-like nematodes and transmitted by Culex, Mansoni and Anopheles mosquitoes. Elephantiasis is characterized by the thickening of the skin and underlying tissues (e.g.) in the legs and male genitals. The adult worms (Wuchereria bancrofti, Brugia Malayi and B. timori) only live in the human lymphatic system. They infect the lymph nodes and block the flow of lymph throughout the body, resulting in chronic oedema, most often seen in the legs and genitals (Davey et al., 2007).

Elephantiasis is prevented by avoiding mosquito bites via using insecticide-treated mosquito bed nets, use of mosquito-repellant creams, wearing protective clothing, clearing mosquito-breeding sites and prompt treatment of infected persons, using albendazole and ivermectin in sub-Saharan Africa or albendazole and diethylcarbamazine in other parts of the world (CDC, 2008).

Encephalitis

This is the irritation and swelling of the brain, mostly due to infections. It is always a rare condition, occurring mostly in the first year of life and decreases with age. Encephalitis is mostly caused by viral infections and many types of viruses can cause it. Exposure to these viruses can occur through:
- Breathing in respiratory droplets from an infected person.
- Contaminated food or drink
- Mosquito and other insect bites
- Skin contact

The virus causes inflammation of brain tissues, (Tolle, 2009). The brain tissues swell and may destroy nerve cells, cause bleeding in the brain and brain damage. Symptoms of encephalitis include fever, mild headache, low energy, poor appetite, confusion, drowsiness, poor temper control, light sensitivity, stiff neck, vomiting, (etc).

Treatment

There are no specific antiviral drugs available to fight encephalitis. Treatment depends on the specific causative organism. Sedatives are used to treat restlessness.

Prevention

Contact with infected persons should be avoided. Controlling mosquitoes may reduce the chance of some infections that can lead to encephalitis (Tolle, 2009).

Houseflies

The housefly (Musca domestica) is a fly of the sub-order Cyclorrhapha and family Muscidae. It is the most common of all the domestic flies. They are large sized, dipterans, which live in close association with man. A housefly’s mouthparts consist of a proboscis with which it sucks up fluid food; the fly can also feed on solid food by first dissolving it in a drop of saliva, produced in its salivary glands. Housefly is not a blood sucker; it transmits disease pathogens mechanically (directly or indirectly) because they have very hairy bodies, they are capable of carrying over 100 disease pathogens such as those causing Typhoid fever, Cholera, Salmonellosis, Bacillary Dysentary, Tuberculosis, Anthrax and parasitic Worms. Because of their high intake of food, they deposit/pass faeces constantly. They are active only in the day time and rest at night (Graczyk et al., 2005).

Disease pathogens carried on the hairs, mouthparts, vomits and faeces of houseflies include:
1. Cysts of protozoans (e.g.) Entamoeba histolytica, Giardia lambia and eggs of Helminths, e.g. Ascaris, lumbricoides, Trichuris trichiura, Hymenolepis nana, Enterobius vermicularis, etc. All of which cause parasitic diseases.
2. Salmonella typhi, vbrio cholerae, (etc), which cause bacterial infections.
3. Viruses that cause poliomyelitis and viral hepatitis A and E etc. (Graczyk et al., 2005).

Sandflies

Sandfly is a colloquial name for any species or genus of flying, biting, blood-sucking dipteran, encountered in sandy areas. Their bites leave large, red itching bumps that may turn into a rash. These bumps are usually several times as itching as mosquito bites and tend to last longer as well. In most species of Sandflies, the females are responsible for biting and sucking the blood of mammals, reptiles and birds, because she requires the blood protein to develop her eggs. Sandflies are the primary vectors of Leishmaniasis and Pappataci fever, both diseases are referred to a Sandfly fever (Sabin, 1955).

Blackflies

Blackflies are members of the family Simuliidae. Most of them belong to the genus Simulium. They gain nourishment by feeding on the blood of animals, including man, although, the males feed mainly on nectar. They are usually small, black or grey with short legs and antennae. Blackflies are the vectors of the causative organisms of Onchocerciasis (river blindness), Onchocerca volvolus. Transmission of the parasite.
occurs through the bite of an infected blackfly while feeding on the human blood (W.H.O., 2010).

**Tse-tse flies**

Tse-tse flies are large Dipterans, found only in tropical Africa (Leak, 1998). The adult flies are blood suckers, both males and females, sucking human and animal blood. They possess piercing and sucking mouthparts (Leak, 1998). Tse-tse flies are vectors of Trypanosomiasis/sleeping sickness, caused by Trypanosomes belonging to the genus *Trypanosoma*. *Trypanosoma brucei gambiense rhodesiense complex* is the causative agent of human Trypanosomiasis, transmitted by two Tse-tse fly groups in Africa, Palpalis and Morsitans groups (Leak, 1998).

**Horseflies**

Horseflies are members of the family Tabanidae. Adult males feed on nectar and pollen, whereas the females require blood meal for reproduction and they prefer mammalian blood. Tabanids are known vectors of human and animal diseases. They are blood-sucking and day-biting dipterans/vectors found in rainforest – like environment in West and Central Africa (Padget and Jacobson, 2008). The species belonging to the genus *Chrysops* are biological vectors of *Loa loa*. Tropical swelling and African eye worm Infection are skin and eye diseases, caused by the Nematode, *Loa loa*. (Table 1)

**Life cycles of dipterans and their vulnerability of control and eradication**

Egg-laying behaviour of the Dipterans is diverse. Some scatter their eggs just below the surface on vegetation or on mineral substrates, others deposit their eggs in deleterious masses (Michelson, 1996). The adult stage is regarded as a reproductive and dispersal phase. Females select suitable oviposition sites where they lay their eggs. The eggs hatch after a period of incubation of varying length, giving rise to larvae, which represent a growth phase. During the larval stage, the insect does almost nothing but nourishes itself and provides the tissues necessary for a later transformation into an adult. This growth period is divided into stages or instars each of which terminates with the moulting of the larval skin to allow increase in size, for the stage that follows (Mclachlan and Hadle, 2001). In the dipterans, there are 4 (four) larval instars. At the conclusion of the final larval instars, there is a dramatic reorganization in tissue structure, initiated by the actions of hormones and the process results in the formation of an adult insect. During this time, the insect is called a pupa, because its external form is now changed and all external activities virtually cease. When the adult tissues are almost fully formed, the fly emerges from its pupal case and spends sometime drying, hardening and expanding its wings, attaining colour and reaching sexual maturity. It is then,
ready to start its cycle once again.

The life cycle of a typical dipteran (mosquito)

Mosquitoes are of the family Culicidae. They go through four (4) stages in their life cycle. Egg, larval, pupa and adult/imago. Adult females lay their eggs in standing water, the first three (3) stages are spent in water environment and last for 5-14 days, depending on the species and the ambient temperature. Eggs hatch to become larvae, then pupae. The adult mosquito emerges from the pupal case as it floats at the water surface. Adults live for 4 – 8 weeks (Blagoderov et al., 2002). Mosquitoes have mouthparts that are adapted for piercing the skin of plants and animals. While males typically feed on nectar and fruit juices, the females need to obtain nutrients from a blood meal (Humans and Animals) before she can produce eggs.

The larval stage

Mosquito larvae have well developed heads with mouth brushes used for feeding, a large thorax with no legs and a segmented abdomen. They breathe through spiracles located on the abdominal segments and therefore, must come to the water surface frequently. They spend most of their time, feeding on algae, bacteria and other microorganisms in the surface. They only dive below the surface when disturbed. The larvae swim through propulsion with the mouth brushes or jerking movements of the entire body. The larvae develop through four (4) stages instars after which they metamorphose into pupae. At the end of each instar, the larvae molt, shedding their skin to allow for further growth (Service, 1997).

Pupal stage

The head and thorax are merged together into a cephalothorax with the abdomen, circling around at the pupal stage. Just as the larvae, the pupae must come to the surface frequently to breathe but they do not feed. The pupae is less active than the larvae. At the end of the pupal stage, the dorsal surface of the cephalothorax splits and the adult mosquito emerges.

Stage/Imago

The duration from the egg to adult stage varies among species and is strongly influenced by ambient temperature. Mosquitoes can develop from egg to adult in 5 days, but they usually take 40 – 42 days in tropical conditions. The body sizes of adult mosquitoes depend on the larval population and the food supply within the breeding water. Adult mosquitoes usually mate within a few days after emerging from the pupal case. The males usually form large swarms around the dusk and the females fly into the swarms to mate. Males live for about a week, feeding on nectar and other sources of sugar. The females obtain full blood meal, rest for few days, while the blood is digested and eggs are developed. This process depends on temperature, but usually takes 2-3 days in tropical conditions. Once the eggs are fully developed, the female lays them and resumes host seeking. The cycle repeats itself until the female dies, their life span depends on temperature, humidity and their ability to successfully obtain a blood meal while avoiding host defenses (Service 1997).

Control and eradication of diptersans

Control measures can be directed at either the immature aquatic stages or the adults or at both stages simultaneously.

Control directed at the immature stages (larvae and pupae)

Biological control method

This method of control is preferred to the insecticidal method, because it does not cause any chemical pollution, but it is usually more difficult to implement and maintain. This method involves the introduction of some biological agents into breeding sites of Dipterans to either feed on their larvae or parasitise them. Some predators that can be used as biological agents include: Fishes e.g. Tilapia, Gambusia Species etc. Tadpoles (larvae of frogs and Toads) etc. Pathogens such as viruses, bacteria, protozoan that can cause larval/ pupal mortality can also be used (Vincent and Carde, 2009).

Genetical methods

This involves the employment of genetic manipulations to alter the original genetic make-up of these flies in the laboratory and afterwards, release them to compete with the natural breeds. These manipulations will either produce flies that are refractory to infection with human diseases, cause great distortions in the sex-ratio, so that excessive number of male mosquitoes are produced or produce sterile males. Genetic control methods aim at either reducing the size of the vector population or replacing it with a non-vector species or strain. Genetic methods are not always simple to implement (Knols et al., 2007; Ito et al., 2002).
Physical method

This method is a simple and very effective method of control. It consists of filling in and eradicating breeding places of dipterans. Larval/pupal habitats, ranging from water filled tree holes, ponds, marshes can be filled with sand. Other container habitats like abandoned cans, metal drums, canoes, pots and tyres can be removed and the breeding sites greatly reduced or eliminated. Water storage jars and village/earthen pots can be covered tightly to reduce the breeding of these flies, (Youdeowei and Service, 1995).

Chemical control

This is simply the use of chemical e.g. paris green, oils e.g. mineral oils, diesel oil, fuel oil or kerosene in the breeding sites of Dipterans. Larvae are killed not just by the oils, physically blocking their tracheae and suffocating them but due to a combination of the fumigant effects of the oil interfering with air intake at the water surface. Larval habitats should be treated with chemicals or oils about every 7-10 days in most tropical areas to ensure that the larvae from eggs are killed before they pupate and give rise to adults. Most insecticides will not kill the eggs, or pupae of flies; their presence in water will not also stop gravid females from ovipositing. Thus chemical control measures against the immature stages of flies are mainly directed at killing the larvae (Vincent and Carde, 2009).

Control directed at adults

Control strategies geared towards adult dipterans include the use of insecticide treated door, bed and window nets. Flit guns filled with pyrethrum, dissolved in kerosene can be used in rooms to kill Dipterans in homes, hospitals, offices, etc. (Youdeowei and Service, 1995). Suitable insect repellents in the forms of oils, lotion, creams or aerosols can be used to provide temporary protection. The repellents contain chemicals like Diethylbazamide (DES), dimethylphthalate (DMP), chlorodeithy/benzamide, etc.

Repellents are applied to all exposed areas of the skin e.g. arms, wrists, hands, neck, face, taking care to avoid the eyes. They can also be applied on clothings. Repellents remain effective for only about 2 hours, but clothings, impregnated with repellents may remain effective for several weeks or months if not washed (Fradin, 1998).Protective coverings/wears are also very essential to controlling adult dipterans. Wears as long sleeved shirt, trousers, stockings, etc.

Dipterans and waste management in Nigeria

Despite the negative roles, dipterans play in disseminating human and animal diseases, they participate fundamentally in the decomposition process of terrestrial and aquatic systems. About half of all dipteran families have larvae that feed on decaying organic matter; while adult flies can often be seen around decomposing substances. It is the larval stages that are most involved with the breakdown process. They feed voraciously on large amounts of dead organic materials, extracting energy, either directly from the substrate or from the digestion of the microflora associated with the substrate (Mason, 1977). The role of these flies in decomposition is physical, rather than chemical.

In Nigeria, several factors are militating against effective waste management, such factors ranging from poor waste disposal habit of Nigerians, corruption, work attitude, inadequate plants and equipments, etc. Our expected sustainable development cannot be attained until adequate waste management practices are adapted/put in place.

The role of scavengers is very important in the planning, implementation and operation of land disposal sites. They are normally part of the socio-economic structure, their displacement from a disposal site can have many direct and indirect consequences (Adewole, 2009). Although, unsupervised and uncontrolled scavenging can be detrimental to the health of the populace as well as personels operating the facility. Exclusion of scavengers from disposal sites is not necessary if their activities are managed and controlled. These scavenging dipterans help in recovering valuable resources that would have been disposed as wastes, for example, the work done by Qing (Qing et. al., 2011)in China discovered the bioconversion of diary manure by BSFL (the black soldiers fly larvae) Hermetia illucens to produce biodiesel and sugar. Many soil-dwelling dipterans play significant roles in the recycling of leaf litter (e.g.) the midges, the craneflies are commonly found on decomposing leaves. The Muscids are minute scavengers found working on the degradation of backyard compost pile, converting them into compost manure.

Most saprophagous flies also e.g. the fruit flies (Drosophilidae) have larval mouthparts, designed to feed on moist or semi-liquid food. They feed on rotting fruits.

The breakdown of vertebrate excrement is of great economic relevance to human societies. A single adult dairy cow can produce on average, a tone of manure in a year. Flies, such as the dung-flies, blow-flies, flesh-flies and even many muscids must be acknowledged for the quick disposal of these materials. When an animal dies, its carcass will be visited by a succession of various insects, especially, Dipterans e.g. blow flies, flesh-flies, the muscids etc (Putman, 1978). The insects mentioned
above will generally be found on exposed carcasses; when they are buried, the coffin fly (Conicera tibialis) of the family Phoridae often found in coffin or on buried bodies play significant role in decomposing and recycling nutrients. These coffin flies burrow into the soil and oviposit directly on the carcass (Smith, 1986). Dead invertebrates e.g. snails are also fed upon by flies.

Life is wholly dependent on the proper recycling of organic matter and with the ever increasing amount of waste products generated by our societies, filth feeders/eaters are more important than ever, thus, the role of dipterans in waste management and disposal should be enhanced under strict supervision and control in our cities to enjoy cleaner and safer environment.

**CONCLUSION**

The dipterans are indeed, insect of great public health nuisance. They act as “vehicles” for disease pathogens that would not have ordinarily gotten to man and his domestic animals. Such diseases as malaria, yellow fever, dengue fever, encephalitis, typhoid fever, sleeping sickness, leishmaniasis, onchocerciasis, loiasis, lymphatic filariasis, etc are spread by this notorious insect group. Despite these negative roles the dipterans play, they are indispensable in the decomposition process of terrestrial and aquatic systems. It is therefore, strongly recommended that the control measures against the dipterans of medical importance outlined in this piece be put in place, both against the immature and the mature stages, while harnessing under strict control, the scavenging dipterans for waste management, especially in Nigerian cities to ensure clearer and safer environment is an ever increasing population.

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