Chapter 12

Major Disease Vectors in Tanzania: Distribution, Control and Challenges

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Additional information is available at the end of the chapter

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Abstract

Disease vectors remain a major public health challenge in spite of efforts done to control across Tanzania. Different disease vectors have been controlled and efforts are on to eradicate them but challenges are still emerging and managed. In spite of all these success, different disease vectors have been observed to have developed resistance to all classes of insecticides used in public health practices in Tanzania.Resistance reports to main different vectors have been coming throughout Tanzania. The resistance of vectors to insecticides has been of different mechanisms depending on species, insecticides and mechanisms of action of the pesticides. Social economic factors and housing style still a major factor for the distribution and foci of vector abundance. The impact of public health intervention has been observed but still disease vector existence is noticed. Careful monitoring of the public health priorities for disease vectors control should be rethought to keep the elimination track live. Different tools such as insecticides use, understanding control measures, vector distribution and human lifestyle can lead to reduced burden caused by disease vectors. This chapter has described mosquitoes, tsetse flies, soft ticks, blackflies, and houseflies in terms of distribution, abundance, control and challenges of eradication in Tanzania.

Keywords: vectors, disease, insecticides, control, Tanzania

1. Introduction

In Tanzania, like any other developing countries, disease vectors are distributed throughout different ecological zones. Vector abundance and distribution depend on the host availability, climate and breeding sites availability [1–3]. In different regions of Tanzania, disease vector abundance depends on the use of intervention tools, human activities, social economic status and knowledge on disease vector control (such as traditional practices) [4, 5].

Disease vectors in Tanzania play different roles in transmitting disease from man to man or from animal to man and vice versa. Mosquitoes from two families of Anophelines (all Anopheles mosquitoes) and Culicines (Aedes, Mansonia and Culex) are potential vectors across the country for malaria, filariasis, dengue, chikungunya and of recent Zika viruses. Tsetse flies of different species are principal vectors of African trypanosomiasis, which is caused by *Trypanosome brucei*, most foci are found around national parks and savannah areas. Soft ticks (Ornithodorous sp) are important vectors of *Borrelia duttonii*, the causative agent of tick-borne relapsing fever in Tanzania. In black flies, the most important genus of medical importance is Simulium that has most of the vector groups such as *Simulium damnosum* complex and *S. naivae* group, which transmit *Onchocerca volvulus* that causes human blindness. House flies are common vectors of human diseases such as pathogens (such as *Vibrio cholerae* and Shigella), viruses of polio, Coxsackie and protozoan such as Entamoeba, cryptosporidium, enterobius and giardia.

The government of Tanzania has been putting much effort to ensure reduction and subsequently control of disease vectors [6–9]. The most important targeted disease vectors include mosquitoes, tsetse flies, soft ticks, black flies and house flies. All of these mentioned disease vectors are distributed in different ecological area with the varying abundance and infectivity [10, 11].

In this chapter, all five disease vectors are discussed with focus in vectors distribution, control and challenges in Tanzania.

1.1. Mosquito (Culicidae)

In Tanzania, the main mosquito vectors for diseases are *Anopheles gambiae* s.l. (including *An. gambiae* s.s., *An. arabiensis* and *An. merus*), *Anopheles funestus*, *Culex quinquefasciatus* and *Aedes aegypti*. In Tanzania, among members of *An. gambiae* s.l. found to be vectors of malaria and filariasis are *An. gambiae* s.s., *An. arabiensis* and *An. Merus* [10–14]. In the past, *An. gambiae* s.s. population dominated the areas with high humidity from Coast of the India Ocean and decreased toward mainland Tanzania where *An. arabiensis* dominated [15, 16]. Currently due to different factors including land use changes, climate change and intervention to uses, the vectors species composition in coastal area have changed with *An. arabiensis* taking an upper hand against *An. arabiensis* [12, 17, 18]. The distribution of *An. arabiensis* and *An. gambiae* s.s. has been observed to occur in different proportions in other regions of mainland Tanzania [19–22]. *An. merus* is still restricted in the coast of mainland Tanzania and Zanzibar [12, 21–25].

Anopheles funestus in Tanzania is distributed throughout the country [10, 13, 26–30]. Among the Sibling species of *An. funestus* complex, *An. funestus* s.s., *An. leesoni, A. rivulorum* and *An. parensis* are the most abundant throughout the country [10, 27, 30]. They have been found to vector malaria and filariasis in Tanzania [13, 31].

The *Aedes aegypti* distribution in Tanzania is countrywide but with more focus on urban areas and areas with high altitude [32–35]. These vectors are found mainly in human settlement with regard to its anthropophilic behavior [36]. These vectors feed during the daytime and breed within the human settlements water holding containers and tanks [35, 37–39] and also in vegetation leave axis [40]. These vectors feed indoors and outdoors [41]. These are the mainly vectors: dengue, chikungunya, yellow fever in Tanzania [35, 42] and ZIKA virus outside Africa [43].

An. gambiae s.s. and *An. arabiensis* breed in clean water exposed to sunlit [44]. The breeding habitat varies in size and type from footprint, abandoned goldmines and drainage ditches, cultivated swamps [45] and Paddy farms [46, 47]. The populations of *An. gambiae s.s.* and *An. arabiensis* decrease with an altitude increase and temperature decrease [48]. Climate change and deforestations in highlands of Tanzania have led to colonization of these vectors in those areas such as in Usambara Mountains [49–51] and Hai district [48]. Farming in highlands has led to productive habitats and subsequently vectors colonization in highlands [45].

An. gambiae s.s. feed indoor and rest indoor due to their behavior of being anthropophilic and endophilic [52]. Due to high bed nets and indoor residual spray coverage, the indoor surfaces with insecticides repel mosquitoes or kill them hence they have forced to be outdoor feeders [53].

An. arabiensis are zoophilic and exophilic [48]. They feed outdoors in bovines and only on unprotected human when the bovines are not available [54, 55]. The use of LLINs and IRS programs affects the indoor feeding behavior of *An. arabiensis* (endophagic) for increasing irritation, knockdown and exophily to mosquitoes [53]. These vectors have developed avoidance behavior for the treated indoor surfaces [53]. Due to genetic feeding behavior of being anthropophilic and zoophilic for *An. gambiae* s.s. and *An. arabiensis*, respectively, the population of *An. gambiae* s.s. has decreased drastically due to high coverage IRS and LLINs, hence shift in population from *An. gambiae* s.s. to *An. arabiensis* in most areas [12, 17, 18]. Both *An. arabiensis* and *An. gambiae* are potential malaria and filarial vectors in spite of control efforts [12].

An. merus breeds in the salt water along the shore of the Indian Ocean [56]. These vectors breed in salt water exposed to sunlit. The distribution of these vectors is limited to Indian Ocean coast. These vectors are anthropophilic and rest indoor. It disease transmission efficiency is restricted to small-scale because of their breeding sites preferences.

An. funestus sibling species that are abundantly found in Tanzania breed in shaded habitats with high vegetation cover [57]. The feeding and resting behavior of *An. funestus* sibling species differs between them depending on the host preference. *An. funestus* s.s. is anthropophilic, endophagic and endophilic. The vector population of *An. funestus* sibling species distribution has been affected with wide range of LLINs and IRS coverage [13, 29, 57].

Culex quinquefasciatus are vectors associated with the urbanization breeding mostly in the polluted habitats such as sewage system, pit latrines and septic tanks [58, 59]. These vectors are distributed throughout the country [60]. In spite of being distributed throughout the country, they are nuisance vectors in the mainland Tanzania, while they are suggested to be vectors of filariasis in the coastal Tanzania [61, 62]. In coastal Tanzania, they transmit filariasis because of high humidity and presence of microfilaria in human population. In mainland Tanzania, *Culex quinquefasciatus* has been considered as one of the potential vectors of harbovirus diseases (Rift Valley fever) vector [32, 35]. *Culex quinquefasciatus* feeds and rests indoors (been endophilic and endophagic) [63, 64].

1.1.1. Mosquitoes control

1.1.1.1. Indoor residual spray

In Tanzania, the classes of insecticides currently used for IRS are pyrethroids; carbamate and organophosphate IRS have been effective by increasing mortality knockdown and exophily of mosquitoes. To some classes of insecticides such as pyrethroids, high resistance has been reported throughout the country, which reduces its efficiency against pyrethroids resistant vectors [19, 20, 65–67].

1.1.1.2. LLINs indoor residual spray

LLINs play two major roles in mosquitoes control. First, it plays a physical barrier role [68] and second, it plays a chemical role for irritating, knocking down and increasing exophily for mosquitoes [68]. Mosquito nets are treated with pyrethroids alone. Of the recent, incorporation of PBO on the LLNs has shown to increase the efficacy of the LLINs against resistant wild populations of mosquitoes [69, 70]. Currently, multiple resistance interested in pyrethroid throughout the country against different vector species threatens the use of LLINs to remain as physical barrier only [68, 70]. LLINs have shown to be more efficient when combined with other tools such as IRS [28, 71] and larval source reduction [72, 73].

1.1.1.3. Larval source management (LSM)

LSM has been applied in small scale and mostly in urban areas. The most areas in Tanzania covered by LSM practice are in the city of Dar es Salaam through urban malaria control [6, 7]. This method has been found to be effective when larval sources are few and manageable (reference). The advantage of this method it utilized well is that the immature stage of mosquito is nonmotile [64]. LSM has shown effectiveness in vectors and disease transmission when done well alone [74–76] in combination with other methods such as LLINs and IRS [72].

1.1.1.4. Use of repellents

Repellents are the compounds used to keep mosquitoes away of the host when applied properly. Among the number of brands of repellents that are available in the market, DEET has been considered as the best reference repellent [77]. Other plant-based repellents include Citronella oil, Lemon grain oil, MRO8, Maskitaa and Ocimum brands have been considered as effective repellents [78–82].

Repellents are used as supplementary tools for LLINs and IRS to prevent bites before retiring to bed or for those getting out of the bed early in the morning in active biting cycle of mosquito. These are effective for all mosquito species.

1.1.1.5. Use of coils

Mosquito coils have irritancy and knockdown effect against mosquitoes. The coil protection time has been found to be 6–8 h [83]. Mosquito coils are burnt inside the house in a room where protected population is expected to have asleep. Burning mosquito coils protects those who are not under bed nets by repelling and forced exophily. The use of coils in areas with LLINs and IRs coverage might strengthen the protection against infective bites.

1.1.1.6. House modification

In Tanzania, in last two decades, there has been much in house structure improvement for better settlements. In traditional houses, more than 70% of mosquitoes entering the house were through caves (the space between a wall and a roof) [84, 85]. The rest of 30% or less was entering through unscreened doors and windows [84, 85]. With the public health education given to community, house improvement in different regions in Tanzania has shown that sealing the caves, screening the doors and windows reduced house entry of mosquitoes [85, 86]. The risk of disease incidences is directly proportional to the house modifications [86–88]. House modifications mostly play a major role in reduction and control of indoor vector dusty and disease transmission risks. House improvements have vividly shown to be effective in different ecological setting in reducing indoor vector density [86–88].

1.1.2. Challenges in mosquito control

Despite of the successful efforts invested in mosquito control in Tanzania, which have led to reduced mosquito-borne disease outcomes, there are still some emerging challenges in control. These challenges are:

1.1.2.1. Insecticides resistance

In Tanzania, the intensive use of insecticides for public health and Agricultural pests control has been the best sources of mosquitoes insecticide resistance [19, 65, 67]. Insecticide resistance has been found against pyrethroids, organochlorines, organophosphates and of recent in carbomates insecticides [89–91].

Insecticide resistances have different mechanisms involved. These mechanisms have enhanced the reduction of toxicity efficiency of insecticides, hence survival of vectors.

In current time, several mechanisms have been realized in Tanzania such as metabolic resistance [91]. This mechanism deals with elevating enzymes efficiency in detoxification of insecticides. The other mechanism is knockdown resistance (kdr), which has been found in both caring genes for Western African *kdr* (*kdr* West) and East African *kdr* (*kdr* East) [19].

1.1.2.2. Behavioral changes

One decade ago after intensive LLINs distribution and scaling up, vectors have changed feeding and resting behavior [53, 92]. Other factors such as house modification of installing window mesh, door mesh and sealing the eaves have caused vectors to feed and rest outdoors [53, 85, 86]. Most vectors such as *An. gambiae* s.s. have changed the natural ecological feeding and resting behavior from feeding and resting indoors [93] to feeding and resting outdoors [53]. This has caused vectors to avoid LLINs contact and indoor sprayed surfaces for biting and resting outdoors. Odor-baited traps with insecticides can be an alternative to be deployed outdoor for controlling outdoor malaria transmission, which cannot be targeted by neither LLINs nor IRS.

1.1.2.3. Urbanization and poor planning

Most urban areas are growing fast with more people migrating from rural for better jobs and opportunities in urban. The settlement demand has caused the emerging growth of unplanned settlement, which subsequently has led to poor land use planning and drainage systems in which mosquitoes have capitalized as potential breeding sites [76]. The increased population in urban has led to demand for more agriculture produce, which have created potential breeding sites that are difficult to be attended at a point of time, hence leading to adult vector productivity in urban [75, 76]. The quality of houses in unplanned urban areas is poor and cannot protect occupants against disease vector, which have house entry behavior such as mosquitoes.

1.1.2.4. Social economic status

The low social economic status mostly in rural and in populated urban areas has caused the impairment of the efficiency of disease control incidences and cases [94]. The low income has caused the communities to fail to improve healthy living status for not meeting the costs of vector control such as house improvements, LLINs and IRS programs when they are not provided for free. In rural setting, the improvement of livelihood, health seeking behavior and use of protective tool such as LLINs have been found to correlate with the income of the family [95–97].

1.2. Tsetse flies (Glossinidae)

1.2.1. Tsetse distribution and occurrences in Tanzania

The tsetse flies (*Diptera: Glossinidae*), referred to by Nash 1996 as “Africa’s bane,” are small insects that resemble a house fly. It ranges in size from 8 to 17 mm. These insects are characterized by a distinct proboscis, antenna with branched arista hairs and by wings that fold at rest and have a characteristic “hatchet” cell. There are 31 living tsetse species belonging to the *Glossina* genus and recent genetic studies have identified new markers meaning that the list may be expanded in the future [98, 99]. However, out of the 31 known species of tsetse flies, only 8–10 species are considered of veterinary and public health importance. Tsetse flies occur in 38 African countries, infesting a total area of 10 million km^2 in sub-Saharan Africa [99]. The *Glossina* fly is solely responsible for the cyclical transmission of the protozoa *Trypanosoma brucei*, which causes human African trypanosomiasis (HAT), also called sleeping sickness and African animal trypanosomiasis (AAT), also known as nagana [100–102].

Humans and livestock who live in tsetse-infested areas are continually exposed to the risk of these infections [102–105].

The genus *Glossina* is divided into three taxonomically distinct groups based on morphological characteristics, habitat requirements and preferred hosts [106]. (i) Subgenus *Morsitans* are mainly found in Savannah areas, including open areas and thickets. The most widely distributed species in Tanzania is *G. morsitans,* followed by *G. pallidipes.* Others in this group are *G. morsitans centralis*, *G. swynnertoni* and *G. austeni.* (ii) Subgenus *Palpalis* inhabit riverine and lakeshore habitats. These include *G. fuscipes fuscipes and G. fuscipes martinii*. (iii) Subgenus *Fusca* can be found in forest areas and near riverbanks e.g., *G. fusca*, *G. longipennis*, *G. brevipalis* and *G. fuscipleuris* [99, 107]. According to a distribution map produced by Ford and Katondo in 1977, two thirds of Tanzania was infested by 10 species and subspecies of tsetse fly. The infestation was distributed between four separate fly belts [108] and is predominantly of the *Morsitans* subgenus, but also includes species from the *Fusca* and *Palpalis* groups, which were restricted toward Lake Victoria and Tanganyika, respectively.

1.2.2. Current situation on tsetse distribution in Tanzania

Since Ford's tsetse distribution map of 1977 for Tanzania, there has been no clear updated distribution map available showing tsetse distribution across the country. However, a number of surveys were undertaken countrywide from 2003 to 2012 to better understand the current distribution. The current updates show that 43% of the country has high to low risk tsetse infestation and 57.4% has no risk. This estimated percentage was surveyed across 16 infested regions in the country [109]. According to a study conducted from 2005 to 2007 [110], tsetse distribution has been altered due to changes in land cover and usage, which is driven by population growth, expansion of human settlements and associated agricultural and infrastructure development activities and land reform policies. These have significantly contributed to the destruction of tsetse habitat ecology, causing a new tsetse distribution limit with fragmented pockets of tsetse flies [111].

1.2.3. Life cycle and reproduction

The life cycle of tsetse is unusual since they do not lay eggs. Instead, after mating, a female tsetse fly develops the egg and young larva within her uterus. A full grown larva is produced every 10 days and quickly deposited in a shady area. Larvae burrow into the soil and pupate virtually immediately, in contrast with other insects. The adults emerge 20–45 days later, depending on temperature. Pupal development does not succeed below 17°C or above 32°C. Thus, each female can produce only one offspring at a time and can produce up to 12 offspring during her typical adult lifespan of 2–3 months. Thus, the tsetse population growth tends to be low. Both male and female adult tsetse take blood meals from a variety of vertebrate hosts every few days and in so doing may cyclically transmit the pathogenic trypanosomes and cause HAT or AT [112, 113].

From precipitin tests, it is concluded that the principal hosts of G. *swynnertoni* from one locality were: (1) a large bovid, possibly roan or kudu, (2) giraffe, (3) wart-hog or bush pig and (4) primate [114]. The absence of abundant antelope species such as impala and duiker from the list of probable hosts and the exclusion of man and baboons from the list of primates suggest that these tests should be treated with a degree of reserve.

1.2.4. Population ecology and dynamics

Tsetse distribution is mainly influenced by density independent (abiotic) factors such as temperature and humidity, which in turn influence vegetation cover. In contrast, fly density is determined by the availability of suitable habitats and hosts, which is influenced by human activity such as expansion of settlement and agriculture, deforestation, livestock movements and habitat fragmentation. These alterations in tsetse distribution and density may have an influence on the transmission of infectious diseases [112].

Generally, tsetse flies are unable to fly for long periods but instead fly in short bursts, with a relatively low capacity for active dispersal. The average total distance flown per day varies between 4.5 and 9 km. They can also be passively dispersed by vehicles, floating vegetation and animals. It is also reported that movements of tsetse flies within a uniform habitat are fairly constant in length and can be related to host-seeking behavior for a blood meal. This behavior is modulated by exogenous and endogenous stimuli. Exogenous stimuli include temperature, vapor, pressure deficit, visual and olfactory stimuli, while endogenous stimuli include levels of starvation, age, sex, pregnancy status and circardian rhythm of activity [115]. Tsetse flies locate their hosts by a combination of olfactory and visual cues. The ability for the tsetse fly spread over a long distance even though in short bursts still causes risk of transmission to new areas or reintroduction to areas/places that have been under control [106].

1.2.5. Tsetse control practices in Tanzania methods (past and current experiences)

Tanzania is among the African countries, which is highly infested by tsetse flies, thus they continue to pose a risk for both humans and domestic animals, despite considerable investments toward control of tsetse over many decades [116]. Attempts to control testes files in Africa including Tanzania were initiated during the colonial era and soon after independence [110]. In the mid 1950s to 1980s, large-scale control programs were implemented, including aerial spraying, clearing vegetation and destruction of hosts to eliminate tsetse and disease eradication seemed a possibility at that time [110, 117].

1.2.5.1. Clearing of vegetation

The former method of clearing vegetation was either by total removal or by removal of only vegetation that was important to support tsetse flies through bush burning. This method was not environmentally beneficial and had left some areas with permanent effects, exacerbated by drought episodes. This control strategy is no longer used due to the environmental degradations it caused [110, 111].

1.2.5.2. Destruction of hosts

Since tsetse flies are hematophagous and feed on wild animals, wild animals have become reservoirs for the trypanosome infections that then spread to domestic animal and humans.

Widespread mass killing of wild animals led to the decline of tsetse fly infestations and ultimately to reduction in trypanosomiasis cases. Despite being effective at the time, the method is no longer acceptable due to its association with environmental destruction [118, 119].

1.2.5.3. Insecticides

After independence, aerial spraying of insecticides on the ground was in use. This method was extensively used in Northern Tanzania, mainly in Arusha, in the early days of control against vectors of sleeping sickness in areas of Babati. The insecticides used were either residual such as DDT, Endosulfan or nonresidual such as synthetic pyrethroid compounds. However, aerial spraying had challenges including how to minimize product loss due to spray drift and ensure maximal deposition on the targeted ground. Despite the method being widely used and considered successful, there was still a challenge with reinvasion of tsetse flies and also insecticide resistance [120]. The methods caused a significant reduction of fly infestations and ultimate control of trypanosomiasis. This method was also considered as being environmentally hazardous and is no longer applied [118, 121].

The use of ineffective methods, the emergence of resistance and environmental concerns motivated the engagement of better strategies; these include the use of chemicals (insecticides) on cattle, traps and targets, bait technology and biological controls such as sterile insect technique.

1.2.5.4. Traps and targets

Traps are black and blue insecticide-impregnated fabric screens that attract the flies by the blue segment, which then land on the black segment and quickly succumb to the insecticides [122]. Apart from the control of tsetse flies, the traps can also be used for entomological surveying, as they attract the flies and trap them upwards. Targets are simpler to traps; both are impregnated with biodegradable pyrethroid like deltamethrin. The efficiency of traps and targets is enhanced by the use of odor attractants such as acetone and cow urine. This technique is important for monitoring and estimating the control and prevention of trypanosomiasis epidemics; they are also important as a suppression tool before other technique was being applied such as SIT [123].

Efficiency of traps and targets varies depending on type of tsetse flies species surveyed, location (habitat) and type of traps/targets used for tsetse collection or survey. For instance, NGU, Epsilon and F3 are markedly superior to the biconical and pyramidal traps for *G. pallidipes* and *G. brevipalpis* [124]. Also, some targets are found to be more efficient when limited to a certain size [125].

The technique is credited as the most ecologically friendly technique [126]. In addition, traps and targets can be used with the combination of live baits to speed up suppression of the vectors before elimination is achieved. In recent years, modifications of traps have been achieved to increase their efficiency in catching specific *Glossina* spp. in specific environments [119, 125]. Despite the method being cost-effective and environmentally friendly, a widespread implementation of this technique in Tanzania has failed, due to lack of proper infrastructures to manage and sustain the traps/targets over large areas and its failure to eradicate residual tsetse populations [127]. The insecticide-impregnated targets have some drawbacks in terms of insecticide efficiency reduction in the targets due to rain, sunlight, wind and dust.

This control method has been present and applied in a sporadic manner. However, Tanzania National Parks Authority (TANAPA) has extensively utilized the technique to control tsetse flies across several national parks and communities around national parks [128]. The tsetse control strategy played a significant role in the control of previous HAT outbreaks to tourists, park staff and surrounding communities in northern parks. This is one of the major achievements by parks control efforts. However, there are still challenges with tsetse flies in national parks, which might be attributed by the fact that there is a possibility of reinvasion from areas in which tsetse flies have not been controlled. Also, the environment and habitats in the parks support the thriving of tsetse, due to the availability of stable vegetation for resting and breeding, abundant supply of blood meal from wild animals and with vegetation attracting large density of tsetse flies [128].

1.2.5.5. Bait technology

Another useful method is bait technology; this can be used in live animals or moving objects such as sprayed vehicles. The technique involves treating cattle with appropriate insecticide formulation, usually by means of cattle dips, or as pour-on, spot-on, or spray-on treatments. The formulations are highly effective against tsetse flies as well as ticks. The method has been used in Mkwaja, Mzeri and Kagera ranches in Tanzania, since the early 1990s [110, 129]. To date, the method is still commonly practiced and easily adopted by farmers. However, there are challenges associated with the effective use of insecticides due to farmer's diluting stock solutions incorrectly, which may led to insecticide resistance [124]. In national parks, vehicle spraying has been used in recent tsetse control programs, whereby vehicles travelling into the Parks are sprayed with insecticides to serve as moving targets. The method attracts flies to the moving object and hence serves as a control of tsetse flies in the national parks. The lower half of a vehicle is sprayed with approximately 16 L of Glossinex® diuted to 0.25 ml/L [128].

1.2.5.6. Biological control

Sterile insect technique (SIT) was used as a biological control method that involves three main steps: (1) production of large numbers of target insects, (2) sterilization of male flies and (3) sustained and systematic release of sterile males over the targeted area with large numbers of flies (March 2013). The method has significantly proved its potential against riverine and savannah tsetse species. A first full-scale project was implemented in Zanzibar Island, Tanzania and the project was successful in eradicating tsetse flies (*G. morsitans morsitans*) in Zanzibar Island (1994–1997), also in Burkina Faso (1980s) and Nigeria (1979–1988). The technique was enhanced by integrating the release of sterile males with the use of targets [99]. The mating of sterile males with females lead to female infertility for the rest of its life span; however, recently this has been shown not to occur in species like *G. fuscipes*. Theoretical models clearly demonstrated that, the method is efficient and cost-effective, as the natural population declines with the increase of the sterile male population [99]. Despite of the method being advantageous, there are challenges associated with this technique such as the quality of the released insects and require a low target population density. The method has failed in some areas, where population targets have been high or when there are other technical and logistic difficulties involved [130]. Other countries have used SIT as part of an area-wide integrated pest management approach in combination with other control tactics to eradicate, suppress, or contain pest population of Diptera, Coleoptera and Ledioptera (Screwworm fly) in the USA, Mexico, Central America and Libya [99].

Unintentional causes of tsetse control also occur when anthropogenic landscape modifications involve the destruction of tsetse habitat. This is influenced by demographic pressure including expansion of human's settlement and increases in agricultural development. This control is very effective and less expensive and has been increasing in recent times; however, it is not a feasible approach to tsetse control [131].

1.2.6. Challenges for tsetse control in Tanzania

Current endeavors in the control of tsetse flies across Tanzania have been hampered by a lack of funds or different priorities and subsequent improper policies set by the government. These challenges began during larger economic structural adjustments about three decades ago and since that time, there has been no embracing of tsetse fly control. Withdrawal of donor support and a reduced role of central government in veterinary services have caused discontinuity of the existing control programs. This has impaired research and capacity building both in terms of infrastructure and manpower. A number of government research institutes are no longer active, nor is there a tailored course for junior tsetse experts. As for livestock keepers, control of parasites is within their means, with high variation to standard procedures, hence increasing the risk of insufficient preparation usage of insecticides and irregular treatment of chemotherapy, which may lead to drug/acaricides resistance potentials.

Another challenge facing tsetse control in Tanzania associates with the identified hot spots for tsetse breeding. These spots are currently confined in protected areas in the form of game reserves and reserved forests. Hence, the effective control can only be achieved by joint efforts between authorities responsible for protected areas like Tanzania National Parks (TANAPA), the Wildlife Division in the Ministry of Natural resources and Local governments. The use of GIS and GPS for recording and updating distribution patterns of tsetse flies and trypanosomiasis can also be useful for control in these pocket locations. It is only through jointly coordinated efforts against tsetse that the vector will be eliminated from the county.

1.2.7. New opportunities in control

The existing collaborations in tsetse control activities through various organizations including TANAPA, Ministry of Health and Social welfare, Ministry of Agriculture, livestock and fisheries development, the Wildlife Division in the Ministry of Natural resources and Local governments must be strengthened and honored continuously for sustainable tangible impacts. Furthermore, the involvement of interested private sectors would strengthen the fight against tsetse flies and trypanosomiasis across the country. The surrounding communities living in hot spot areas must be well involved in tsetse control activities to ensure sustainability of the control tsetse and trypanosomes efforts.

More research projects must be prioritized as a way forward to increase the efficiency of existing control methods. Updated data are crucial for efficient control of diseases. There is a significant work undertaken in reporting HAT cases, but this has not been the case for AAT. Researches into improved techniques are also needed, such as methods to maximize the lifespan and durability of tsetse fly targets and traps.

1.3. Houseflies (Muscidae)

In Tanzania, houseflies are distributed throughout the country colonizing both rural and urban areas [132, 133]. These disease vectors have been found to consume and survive well in household water throughout the country. Houseflies feed on several types of substances, almost all food materials for human, carcasses, rotting material, excreta and other inorganic materials. In feeding, the physical state of food material causes different feeding modes. For thin fluids, such as milk and tea, the labella are placed in contact with food, which is then sucked through the pseudotrachea. When the feed is in semisolid state such as fecal material, food leftovers and sputum, the labella are completely everted and food staff is suckled up directly into food channel. When feeding on a complete solid material such as sugar, cooked meat and dry blood, the labella and prestomal teeth which surround the food channel scrape the solid food. Then, a fly moistens small food particles. In Tanzania, the abundance of houseflies have been associated with poor hygiene and lack of sufficient amount of water supply in populated areas. The main houseflies species of medical importance belongs to genus *musca*. The important species in Tanzania are *Musca domestica* and *Musca sorbens* [132, 133]. These are the main species distributed and have the impact on public health for transmitting microorganisms for mostly trachoma, diarrhea and cholera [132, 134, 135].

1.3.1. Medical importance of housefly

1.3.1.1. Disease vector

Houseflies are the main vector transmitting microorganisms for mostly trachoma, diarrhea and cholera

1.3.1.2. Nuisance

The landing of houseflies on face frequently is disturbing and making a person uncomfortable. High occurrence of the houseflies makes house occupants uncomfortable which is regarded as nuisance.

1.3.2. Control

1.3.2.1. Treated curtains

Curtains are treated with insecticides with low mammalian toxicity such as pyrethroids.

1.3.2.2. Spray

Use of spray aerosols in walls and roofs.

1.3.2.3. Treated cords

Insecticide treated cords are hanged indoor for flies to rest on them and pick up lethal dose of insecticide, hence increase mortality of flies.

1.3.2.4. Screened windows and doors

Screened windows and doors are physical barriers with for houseflies to enter the house.

1.3.3. Challenges

Due to poor planed urban and rural waste management, the perfect control of the house flies has been a task to be tackled in cross cutting manner.

1.4. Bedbugs (Cimicidae)

Bedbugs are distributed in all urban and rural areas of Tanzania [136–139]. Bedbugs distribution has been mostly associated with the human being movements worldwide [140]. This might be the case in Tanzania as well. Mostly, the bedbugs infestation is associated with poor hygiene and poor housing. In houses, bedbugs have been breeding in furnitures, bed and house wall cracks. They are nocturnal, but when they are hungry, they feed at any time on availability of host.

1.4.1. Control

1.4.1.1. Indoor residual spray

Different classes of Insecticides approved for use against pests of public health importance. The spray is targeted in furnitures, wall cracks and beds.

1.4.1.2. Use of LLINs

The wide coverage of LLINs increases the exposure of bedbugs to insecticides and increases mortality.

1.4.1.3. Hygiene

Household hygiene prevents and limits the distribution and survival of bedbugs.

1.4.1.4. House style improvement

House structure improvement from traditional to modern houses has led to increased hygiene and reduced the possible breeding sites for the bedbugs.

1.4.2. Medical importance

1.4.2.1. Annoyance

The highly bedbugs infested houses per room cause disturbance to occupant who are not been able to sleep. This causes uncomfortability for the room occupants.

1.4.2.2. Anemia for children

In highly infested family houses, the children and infants suffer from anemia due to high blood loss.

1.4.2.3. Sleeping stress

This is caused with high biting rates per night, which reduced the interrupted sleeping time.

1.4.3. Challenges

1.4.3.1. Insecticide resistance

Due to wide coverage of LLINs and IRS programs across Tanzania, bedbugs resistances have been reported from all areas with intensive coverage of LLLINs and IRS, due to extended exposure of insecticides as reported from Tanga, Zanzibar and Bagamoyo [136, 138, 139].

1.4.3.2. House improvements

House structure improvement progresses still in low rate from rural to urban areas, hence handicapping the efforts of bedbug control.

1.4.3.3. Human movements (student to school and travelers)

Human movements from infested to uninfested areas cause the spread of bugs and human movements cannot be restricted.

1.5. Black flies (Simuliidae)

Black flies are major Africa vectors of human onchocerciasis (river blindness), caused by filarial nematode *Onchocerca volvulus*. In Tanzania, foci are in southern central and northern east, which include Ruvuma focus and the Kilosa, Uluguru, Tukuyu and Mahenge and Amani forest where parasite transmission is mediated by *S. damnosum* s.l. Members of *S. neavei* group are the principal or sole vectors in two or three foci; they are associated with freshwater crabs and also known to attack human population [141–143]. All these foci are either located along the river valley or clustered along the Arc chain of mountains.

1.5.1. Medical importance

1.5.1.1. Annoyance

Black flies cause serious biting problems, although the severity of the reaction to bites differs in different individual, localized swelling and inflammation, which might be accompanied by irritations for several days.

1.5.1.2. Onchocerciasis

This is a nonfatal disease, called river blindness, which is caused by the filarial parasite *Onchocerca volvulus*. There are no annual hosts, the disease is not zoonosis. Black flies are the only vector of human onchocerciasis. Their feeding habit of tearing skin and feeding makes it possible for parasite to penetrate the human skin.

1.5.2. Control

1.5.2.1. Use of repellents

The reduction of human—black flies contract can be achieved by using repellents such as DEET or wearing pyrethroid-impregnated or sprayed clothing.

1.5.2.2. Use of insecticides (larviciding)

The water rivers found to be habitats are sprayed with larvicidal such temephos or *Bacillus thuringiensis var. Israelensis* (Bti). In areas with high infestations, applications should be repeated in 1–2 weeks interval, throughout the year to prevent recolonization. Due to the nature of habitat, the ground application of insecticides is more difficult, hence the aerial application is recommended.

1.5.3. Challenges

It has been difficult to reaching all the active breeding sites throughout the year.

1.6. Soft ticks (Argasidae)

Soft ticks have worldwide distribution. There are 193 species, which belongs to four genera. The most medical important genus is Ornithodoros. The most important species is *Ornithodoros moubata,* which is a vector-borne (endemic) relapsing fever (*Borrelia duttonii*). In Tanzania, soft ticks are distributed across the country. The regions mostly infested are Dodoma, Iringa, Mara, Dodoma, Mwanza, Tabora, Morogoro, Shinyanga, Manyara and Arusha and Zanzibar prisons [144–146]. The distribution of eggs, larvae, nymphs and adults of soft ticks is usually restricted to the infested structures occupied by any host [145, 147]. The most identification feature in soft tick is the absence of scutum (shield).

1.6.1. Medical importance

1.6.1.1. Tick-borne relapsing fever

Ornithodoros moubata transmits *Borrelia duttonii,* which is ingested during blood feeding and multiplies in the midgut ready for being transmitted to the host during next feeding.

1.6.1.2. Q-fever

Argasidae ticks can be vector but the most serious vectors are ixodid ticks.

1.6.1.3. Tick-bite allergies and tick paralysis

Ticks cause allergies such as itching, skin rashes and fevers.

1.6.2. Control

1.6.2.1. Use of repellents

The standard approved repellents for the use against soft ticks are DEET, Picaridin-based products or indalone.

1.6.2.2. Use of insecticide treated clothes

Clothes are treated with recommended dosage of pyrethroid like permethrin.

1.6.2.3. Indoor residual spray

Infested houses are sprayed with insecticides such as organophosphates, carbamates, propoxur and pyrethroids targeting cracks on walls and floors, furnitures and all possible sites where ticks can be hiding.

1.6.2.4. Frequent house maintenance

Plastering of house walls and floors can play a major role in reduction of hiding and breeding sites of soft ticks.

1.6.3. Challenges

1. Insecticides resistance among soft ticks population.
2. Poor house structure and quality in infested rural areas.
3. Culture and belief of some tribes of staying with animals in the same shelter.

2. Conclusion

Main diseases vector (mosquitoes, tsetse flies, black flies, sand flies and soft ticks) control in Tanzania has taken a new direction with great success in population decline. Community awareness has been done for long with aid of government and donor project funds for vector control. Community involvement during the campaign for vector control is an asset, which needs to be natured for maintaining the attained progress and go beyond. Community-based vector control programs should be institutionalized and operationalized by community for maintenance and sustainability.

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