Survey of urban mosquitoes species (Diptera: Culicidae) with focus on waste water channels as larval habitats in Nairobi industrial area, Kenya.

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Summary

Background: **A cross sectional study to establish the levels of heavy metals and other potentially harmful elements (PHEs)present in samples obtained from selected open waste water channels in Nairobi industrial area (Kenya) was carried out. The waste water channels selected were those near the factories or those directly discharging from factories. The samples collected included mosquitoes (larvae and adults), waste water, green algae, and soil. Unmaintained open waste water channels are among the man made features that enhance the breeding of urban mosquitoes because they tend to have overgrown vegetation and trapped solid wastes which slow or inhibit the waste water flow. Different mosquito species have previously transmitted arboviruses including those responsible for dangerous fevers such as West Nile, Rift Valley, Zika, Dengue, Yellow, and Chikungunya among others in different parts of the world. The study area (Nairobi industrial area) neighbors several densely populated informal human settlements. This paper specifically reports on composition and distribution of mosquito species obtained from the study area.**

Methods: **The fourth instars mosquito larvae were collected from waste water channels using the standard dipping method. Adult mosquitoes were trapped using the center for disease control and prevention (CDC) light traps. Purposive random sampling for mosquito adults and larvae was carried out in industrial premises and waste water channels respectively at seven locations. This involved selecting sampling sites from which mosquito samples were likely to be obtained. The mosquitoes were then microscopically identified using taxonomic keys for the Ethiopian and East African region.**

Results: **Out of 2,926 adult mosquitoes trapped, 12 species were identified including *Cx. pipiens* (95%); *Cx. Vansomereni* (2.6%); *Cx. zombaensis* (1.4%); *Cx. univittatus* (0.34%); *Cx. theileri* (0.21%); *Ae. aegpti* (0.14%); *An. maculipalpis* (0.03%); *An. squamosus* (0.03%) and other culicid species (0.20%). Of these adult mosquitoes,**

94% (2753/2926) were females and 6% (173/2926) were males giving a male: female ratio of 1: 16 when using CDC traps. Of the 4,679 mosquito larvae scooped from the waste water channels, 4 species were identified including *Cx. pipiens* (99.34%); *Cx. vansomereni* (0.51%); *Toxorhynchites brevipalpis* (0.13%) and *Aedes* mosquito (0.02%).

Conclusion: **The majority of mosquito species obtained were culicid, *Culex pipiens* for both adults and larvae. A few *Anopheles* and *Aedes* populations were obtained. Unmaintained open waste water channels seen\med to enhance the breeding of urban mosquitoes in the study area. The ecology of these mosquitoes should be studied further to enhance surveillance and controlin order to minimize the risk of mosquito borne viral infections or any other re-emerging mosquito-borne infections to the residents of Nairobi, in particular those living in the informal settlements near Nairobi industrial area, Kenya.**

Keywords: urban, mosquitoes, *Culex pipiens*, waste water, industrial area, Nairobi

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Introduction

There are several factors that create conducive environment for breeding of urban mosquitoes. Piles of garbage, used tires and empty containers may trap water in which the mosquitoes can lay their eggs. Long grass and unattended vegetation along the streams and rivers in urban areas exacerbate breeding rates by creating suitable habitats for the adult mosquitoes. Waste water channels in residential and industrial areas may also offer mosquito breeding sites and in addition the waste waters may contain an assortment of organic materials that are suitable for the growth of the larvae [1]. Waste water may possibly contain certain chemical substances that may interfere with the survival of the larvae and the pupae. However such an occurrence may be location specific. Crowded buildings, incomplete constructions, slums and poor housing facilities, open drainage systems, uncollected solid wastes, animal rearing activities, growing and watering crops and having dark or shaded environments in urban setup may also contribute to increased mosquito population. Culicid mosquitoes prefer living in areas of high human population density and breeding in polluted pools of water associated with human activities [2, 3]. Inadequate vector control strategies, policies and programs especially in developing countries may lead to increased survival of the urban mosquitoes. Mosquito species in the genera *Anopheles, Aedes* and *Culex* that have wide ranging or suitable environmental tolerances have benefitted from anthropological environmental change and can thrive in urban areas [4].Previous studies have shown that *Anopheles* mosquitoes are day/night feeders and breed in both permanent and flood waters; the *Aedes* are daytime biters that prefer breeding in flood waters and rock pools while *Culex* mosquitoes are evening/dusk feeders and breed in both flood and permanent waters [5]. However, according to Townroe & Collaghan [6], proliferation of artificial container habitats in urban areas has generally benefitted urban adaptable mosquito species globally.

Other than being nuisance biting insects, urban mosquitoes have the potential of spreading infections of medical importance. Members of the culicid mosquitoes, in particular the *Culex pipiens* complex serve as vectors for several arboviruses that include St. Louis encephalitis, West Nile, Japanese encephalitis, Sindbis, and Rift Valley fever viruses [7] and they can also transmit helminthes responsible for filariasis in humans [8]. *Culex pipiens* were found to be the most abundant species of mosquitoes in United Kingdom (UK) urban areas and inhabiting areas near peoples' houses [6]. *Aedes* mosquitoes are now widely spread in tropical and subtropical areas including Africa, the surrounding tropics and subtropics including south eastern US, the Middle East, South East Asia, Pacific and Indian Islands and Northern Australia [9]. In particular, *Aedes aegypti* thrives in densely populated areas which lack reliable water supplies, waste management and sanitation [10] and it is also known to transmit several arboviruses responsible for several life threatening infections including Dengue, Chikungunya, Yellow and Zika fevers. Rift valley fever virus (RVFV) which is an arthropod-borne human and animal life threatening pathogen found in Africa and the Arabian Peninsula is also maintained by the mosquitoes in the *Aedes* genus and amplified by the mosquitoes in the *Culex* genus [11]. In sub Saharan Africa, increased urban *Anopheles* mosquitoes has been attributed by poor housing, lack of sanitation, poor drainage systems, broken pipes and pools formed at construction sites, urban agriculture and unplanned developments [12, 13, 14]. Various species of the genus *Anopheles* may not be involved in malaria transmission because of their rare occurrence and weak interactions with humans [15]. Of the approximately 430 *Anopheles* species, only 30 to 40 species can transmit malaria in nature [16]. .*Anopheles gambiae* are the most important vectors of human malaria in tropical areas particularly in the sub-Saharan Africa [17]. In a previous study carried out in Nigeria by Okwa and others [18], *An. gambiae* had the highest sporozoite rates followed by *An. funestus* and finally by *An. arabiensis* which had the least vector competency.A similar study in western Kenya indicated that *An. gambiae* s.s is the primary vector of malaria parasites while *An. funestus* s.l is considered a secondary vector [19]. *Anopheles* mosquitoes have been reported in malaria non-endemic areas as well as in places where malaria has been eliminated. This has increased the risk of spreading malaria to new areas and re-introduction of malaria in other areas. Other than malaria transmission *Anopheles* mosquitoes have been reported to carry arboviruses including those responsible for West Nile and Japanese Encephalitis [20, 21] as well as viruses that cause O'nyong-nyong and Chikungunya fevers [22]. It has also been hypothesized that *Anopheles* mosquitoes transmits viruses that causes mild transitory illness that could culminate into a brain tumor [23]. There are several species of mosquitoes in the genera *Anopheles, Culex, Aedes* and *Mansoni* that transmit nematode parasites of medical importance including *Wuchereria bancrofti* and *Brugia malayi* that cause lymphatic human filariasis [24].

The current study was therefore designed to sample the mosquito species from randomly selected sites in the industrial area of Nairobi, Kenya. The composition and distribution of the mosquito species established was expected to highlight the potential public health risk on the human population residing in the informal settlements neighboring the study area. The study was also important in establishing the distribution of mosquito species in the study area in view of the changing climatic and weather parameters in many tropical areas of the world. In order to establish a more reliable data on the composition and distribution of mosquito species in the study area, both the larvae and adults were sampled in each sampling site. The species composition data on the adult mosquitoes was to be compared with that of the larvae and make a reliable conclusion. The underlying assumption was that the mosquito larvae in the waste water channels were eventually developing into adults and therefore the species composition of the two were to be more or less correlated.

Methods

Study area and sampling sites

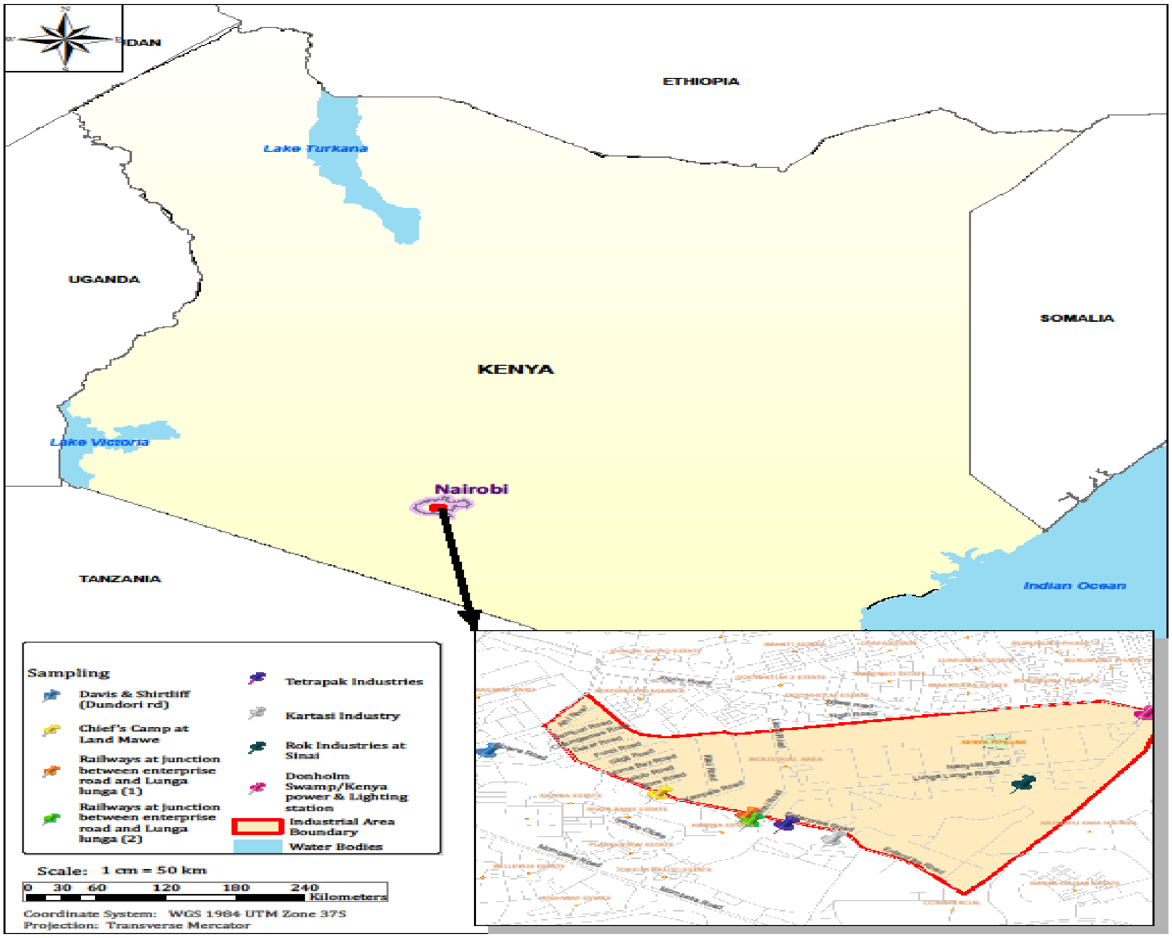
The study area was Nairobi industrial area in Kenya (Figure 1). The area had varying industrial activities and several other significant features that included informal human settlements near and almost around it hence high population density, crowding and congestion. Other features that were outstanding included, poor housing facilities, open waste water drainage systems from the factories and residential areas, increased construction activities that have attracted many casual workers, poor solid wastes management practices in some places, heavily polluted streams, dense vegetation especially behind the factories, several swampy areas and moderate livestock rearing activities among others.

The samples were collected from eight different sites coded A to H. The sites were Tetrapak (A); Chief's Camp at Landmawe (B); Two sites at Railways – Enterprise/ LungaLunga roads (C & D); Davis & Shirtliff along Dondori road (E); Kartasi industries (F); Rok industries-Sinai (G); and Donholm Swamp/Kenya Power and Lighting Station (H). The sampling sites are shown in Figure 1. From each site adult mosquitoes and mosquito larvae were collected apart from site C where adult mosquitoes were not collected and site B (Chief's camp), site F (Kartasi Industries) &site H (Donholm swamp) where mosquito larvae were not available.

Trapping of adult mosquitoes

Adult mosquitoes were trapped outdoor from each site using surveillance standard CDC light traps as described by Mweya and colleagues [25] but the bait used in this case was carbonated dry ice. The traps were set in potential breeding sites and amidst the vegetation where applicable (Figure 2). The trapping was done within the industry compound and it commenced from 6:00 PM in the evening up to 6:00 AM in the morning each day. The number of traps set per sampling site ranged between 4 and 10 depending on the size of the industry compound. Seven traps on average were set in each sampling site per night for seven nights during the first two weeks of August, 2015.

Fig 1: The study area showing sampling sites that were coded by letters A to H in the data table.

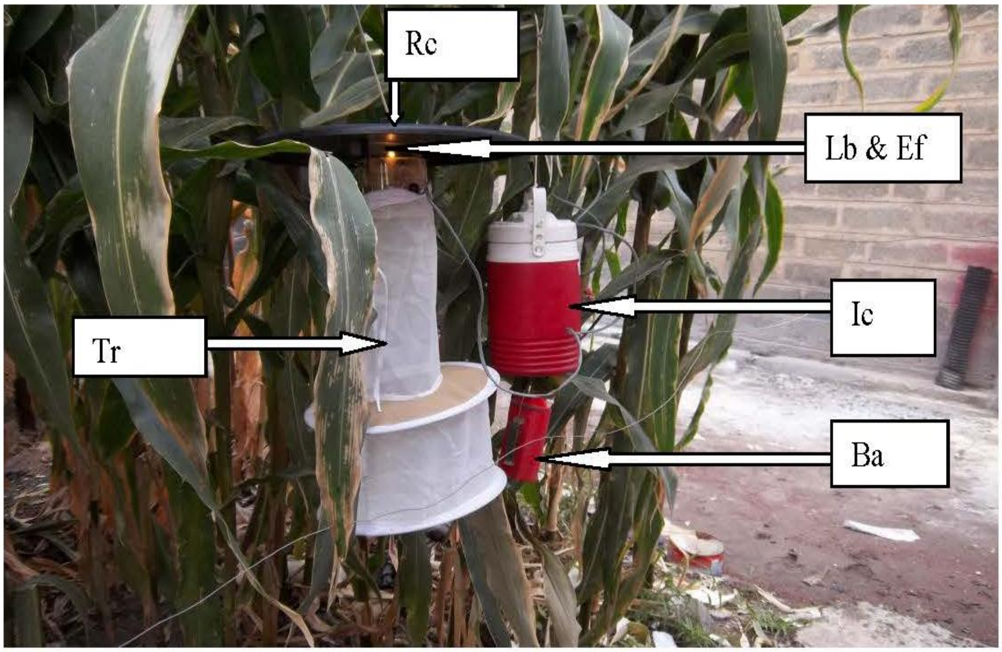


Key: A – Tetrapak; B – Chief's Camp Landmawe; C & D – 2 sites at Railways - Enterprise/Lungalunga roads junction respectively; E – Davis &Shirtliff; F – Kartasi Industries; G – Rok Industries at Sinai; H – Donholm/Kenya Power station. There was no trapping of adult mosquitoes at site C.

Processing and preserving of the trapped adult mosquitoes

The mosquitoes were processed as described by Tchouassi and colleagues [26]. Briefly, every morning the mosquitoes trapped were anaesthetized while still in the trap using triethylamine and after a short while the mosquitoes were sorted from other insects that might have been trapped, counted and put in Nunc tubes and then preserved in liquid nitrogen until when they were required for identification in the laboratory.

Fig 2: CDC Trap No. 5 (a few minutes after setting) hanging from within Cornplants next to thewatchman's shelter near the warehouses at Railway site.



CDC trap parts: Rc – rain cover, Tr –trap, Ba – Battery, Ic – Dry ice cooler, Lb & Ef – Light bulb and Electric fun.

Collections of mosquito larvae

Mosquito larvae were collected during the day preferably midmorning, from open waste water channels within the selected sites in the study area (Figure 3). The larvae sampling was carried out from seven different sites for seven days. Three dips were taken to obtain the larvae using the standard 350 mL dipper from the waste water. In habitats with less than ten larvae in three dips, additional two dips were taken. Dipper contents were transferred onto white plastic trays. The number of larvae were counted and reported as the average number of larvae per dip per habitat. The collected larvae were placed in plastic Whirl-Pak® bags (BioQuip, Rancho Dominguez, CA) filled approximately half full with water from the collection site. The Whirl-Pak containing the samples was then tightly closed to retain air before transporting to the laboratory [27], where they were preserved and later identified.

Fig 3: **Waste water channels at Railway site from which the mosquito larvae were obtained.**

The trash and overgrown vegetation was an indicator of the likelihood of channels getting clogged.

Preservation of the mosquito larvae

The mosquito larvae were preserved for identification using the procedure described by James-Pirri and others [28]. Briefly, the mosquito larvae were retrieved from the whirl packsand placed in hot water at a temperature of 87°C for 50 seconds after which they were removed using a strainer. The larvae were then preserved in Dietrich's solution and later transferred into 75% ethanol for further preservation.

Morphological identification of the mosquitoes

Mosquito larvae and adults were identified morphologically to species under a stereo-microscope using appropriate mosquito taxonomic keys for the Sub Sahara Africa and in particular the East African region [29, 30, 31].

Data analysis

SPSS version 17.0 was used to carry out descriptive data analysis.

Ethics approval, consent and research permit

Ethics approval and consent for participation was not applicable. This research was however reviewed, funded and authorized by Daystar University Research, Publication & Consultancy Committee. The permit to carry out the research was further awarded by National Commission for Science, Technology and Innovation (NACOSTI), Permit number – NACOSTI/P/15/8787/5184. Further authorization to collect data from Nairobi industrial area was approved by County Commissioner, County Director of Education, and Deputy County commissioners of Starehe and Makadara Sub Counties in Nairobi. Permission to sample mosquitoes from each industry premises was given by the industry/factory management.

Results

Species of adult mosquitoes

Figure 4, shows some of the trapped mosquitoes immediately after being anaesthetized using triethylamine and just before preservation and microscopic identification. Table 1 gives a summary of the mosquito species identified.

Fig 4: Showing preserved adult mosquitoes trapped from Donholm-Kenya Power Station Sampling site at Nairobi industrial area before microscopic identification.

A total of 2,926 adult mosquitoes were trapped and 12 species were identified including *Cx. pipiens* (95%); *Cx. vansomereni*(2.6%); *Cx. zombaensis* (1.4%); *Cx. univittatus* (0.34%); *Cx. theileri* (0.21%); *Ae. aegpti* (0.14%); *An. maculipalpis* (0.03%); *An. squamosus* (0.03%) and several other culicid species (0.20%). Of the trapped adult mosquitoes, 94% (2753/2926) were females and 6% (173/2926) males giving a male: female ratio of 1: 15 when using a CDC traps (Table 1).

Table 1: Showing a summary of the identified adult mosquito diversity.

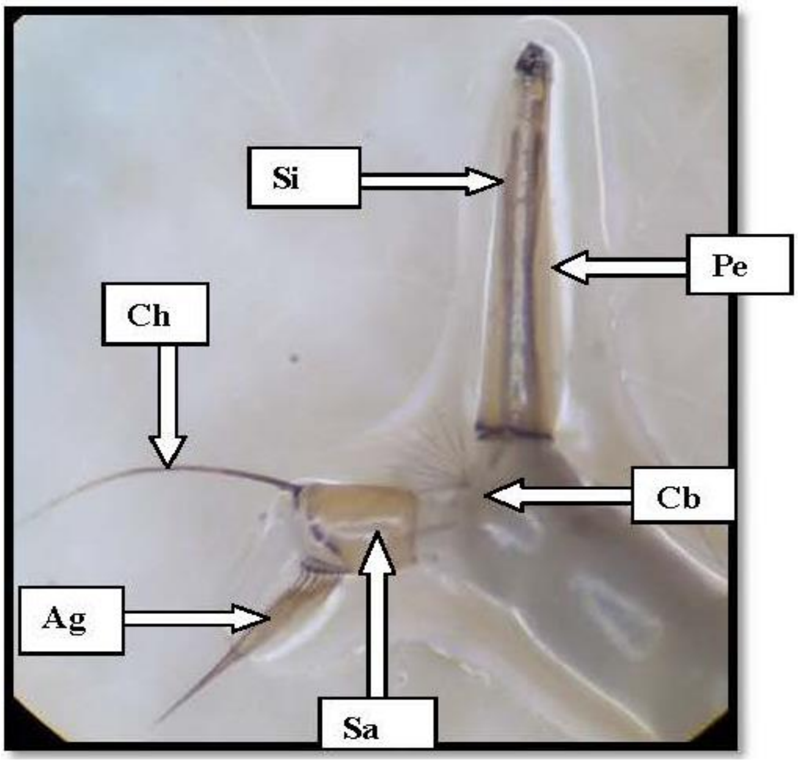
Species	Site	Number	Percent	Male: Female ratio
Cxpipiens	[a]All sites A to H	2779	94.98	148: 2631 (1:18)
Cxvansomereni	B, D, E, F, G, & H	77	2.63	22: 55 (1:3)
Cxzombaensis	A, D, F, &H	41	1.40	3: 38 (1:13)
Cxunivittatus	B, D, E, & H	10	0.34	0: 10 (females)
Cxtheileri	B, F, & H	6	0.21	0: 6 (females)
Cxbitaeneorhynchus	H	3	0.10	0: 3 (females)
Cxtigripes	B	2	0.07	0: 2 (females)
Cxantennatus	H	1	0.03	0: 1 (female)
Cxannuliovis	F	1	0.03	0: 1 (female)
An. maculipalpis	G	1	0.03	0: 1 (female)
An. squamosus	E	1	0.03	0: 1 (female)
Aedesaegypti	H	4	0.14	0: 4 (females)
TOTAL		**2926**	**100.00**	**Average: (1: 15 ratio)**

[a]**Key**: A – Tetrapak; B – Chief's Camp Landmawe; C & D – 2 sites at Railways - Enterprise/Lungalunga roads junction; E – Davis &Shirtliff; F – Kartasi Industries; G – Rok Industries/Sinai; H – Donholm/Kenya Power station. There was no trapping of adult mosquitoes at site C.

Species of mosquito larvae

Figure 5 showa mosquito larva that was preserved in Dietrich's solution before its microscopic identification with some of the taxonomic morphological features being evident. Of the 4,679 mosquito larvae scooped from the waste water channels, a total of 4 species were identified including *Cx. pipiens* (99.34%); *Cx. vansomereni* (0.51%); *Toxorhynchites brevipalpis* (0.13%) and *Aedes* mosquito (0.02%) which wereidentifiable up to the genus level (Table 2). The waste water channels at site D (Railways – Enterprise/Lungalunga roads junction) that contained sewage overflow, yielded 19.5% of the total mosquito larvae collected.

Fig 5: Showing a 4th instar mosquito larvae which were preserved in Dietrich's Solution with its posterior morphology evident



Key:- **Si** – Siphon, **Sa** – Saddle, **Ch** – Caudal hair, **Pe** – Pectin, **Ag**-Anal gills, and **Cb** – Comb. These features were key in morphological identification of the larvae.

Table 2: Summary of the identified mosquito larvae

Species	Number	Site/Source	Percent
Culexpipiens	4648	A, D, & G	99.34
Culexvansomereni	24	D,	0.51
Toxorhynchitesbrevipalpis	6	D	0.13
Aedes species	1	D	0.02
TOTAL	**4679**		**100.00**

Key: A – Tetrapak; B – Chief's Camp Landmawe; C & D – 2 sites at Railways Enterprise/Lungalunga roads junction; E – Davis &Shirtliff; F – Kartasi Industries; G – Rok Industries/Sinai; H – Donholm swamp/Kenya Power station. There were no mosquito larvae obtained from sites B, C, E, F and H.

Discussion

In this study, about 95% of the adult urban mosquitoes trapped using CDC light traps and about 99% of the identified mosquito larvae belonged to the *Culex pipiens* species. Waste water channels that were rich in organic matter like combined sewage overflow in the study area, yielded more larvae. This observation was in line with a previous study by Vazquuez-Prokopec and colleagues [32] in which *Cx. quinquefasciatus* population was significantly higher in combined sewage overflow affected streams. Sewage overflow into streams enhance oviposition of female *Cx. quinquefasciatus* [33]. According to Asgharian and others [34], *Cx. quinquefasciatus* (the southern house mosquito) and *Cx. pipiens* (the northern house mosquito) are the most common members of the *Cx pipiens* complex. *Cx pipiens* are the most common mosquitoes in urban areas that are known to breed in dirty and polluted water. This was the exact situation in Nairobi industrial area, Kenya where the majority of the mosquitoes obtained in the current study for both the larvae and adults were of *Cx pipiens* species. *Culex pipiens* are vectors for human lymphatic filariasis in the tropics and many other arboviral infections including West Nile fever (WNF), Rift Valley fever (RVF), St Louis and Japan Encephalites among others [35].

According to Chancey and colleagues [36], Culex mosquitoes are the natural vectors of West Nile virus while birds can develop sufficient viremia that can infect mosquitoes. The other species of Culex obtained from the study area included *Cx. vansomereni, Cx. zombaensis, Cx. univittatus, Cx. theileri, Cx. annuliovis, Cx. antennatus, Cx. tigripes* and *Cx. bitaeneorhynchus*. These mosquitoes have previously been trapped in many different parts of Kenya [37, 38, 39, 40]. Among these Culex species, Rift Valley fever virus (RVFV) has previously been detected in *Cx. antennatus*, *Cx. vansomereni*, *Cx. zombaensis*, *Cx. univittatus* and *Cx. bitaeniorhynchus* in Kenya [41, 42, 43, 40]. According to Harbach [44], *Cx. antennatus* is widely distributed in Africa and Middle East and it is a vector of WNV and RVF. *Culex antennatus* are commonly found in swamps, ponds, ditches, seepages and rice fields, and although they are zoophilic, they enter houses to bite man. Previous reports indicate that WNV has also been isolated from the larvae of *Cx. univittatus*s.l in Kenya [45]. *Culex vansomereni* has been shown to be a competent vector for WNV [38]. *Culex theileri* species has a wide distribution in all parts of South Africa, East Africa, Sudan and the Mediterranean region [46]. *Cx. theileri* has been suggested to be a potential vector of *Dirofilaria immitis* in Spain [47] and has been suspected to be a competent vector for human and animal pathogens including arboviruses of medical importance [44, 48]. Previously, Pongola virus strains were isolated from *Culex zombaensis* (Theobald) collected from Marsabit in Kenya [39]. Therefore all the *Culex* mosquito species that were trapped in the current study area have the potential of spreading emerging and re-emerging viral diseases especially with the ongoing climatic changes globally. The mosquitoes of the species *Toxorhynchites brevipalpis* are the largest known and the adult females are non-haematophagous, feeding on only nectar and other plant derived sugar sources [49]. The larvae of *Tox. brevipalpis* mosquitoes are predacious and feed on the larvae of other mosquito species, but in absence of a suitable prey they feed on detritus or exhibit cannibalism [49]. *Toxorhynchites brevipalpis* larvae were sampled at Railways site from an open waste water channel that had combined sewage overflow and clogged with both dead and living vegetation materials. The presence of Toxorhynchites mosquito larvae in the waste water channels was important because they could act as biological control of other mosquito larvae. Studies on the control of mosquito vectors using Toxorhynchites mosquitoes have been carried out in various parts of the world including India [50, 51, 52, 53].

The genus Anopheles contains over 400 species [54], of which 30-40 are vectors for human malaria [55]. *Anopheles* mosquitoes prefer breeding in both permanent and flood waters. The most important vector of malaria in sub-Saharan Africa is *An. gambiae* s.l, and in the current study, none was found among a total of 2926 mosquitoes trapped in Nairobi industrial area, Kenya during the first two weeks of August, 2015 from eight selected sites.According to Tchouassi and colleagues [40], there has been an increased association of anopheles mosquitoes with arboviruses. Previously, arboviruses including the RVFV have been isolated from *An. gambiae, An. funestus, An. coustani* and *An. squamosus* [56, 42, 43]. Isolation of Onyong'nyong virus [57] and Semliki Forest virus [39] from *An. funestus* has previously been reported in western Kenya. Therefore the sampling of *An. squamosus* and *An. maculipalpis* in the present study was significant. Despite their zoophilic behavior, the sub Saharan *An. squamosus* mosquitoes have been reported to show significant anthropophilic tendencies in Southern Zambia hence increasing their role as potential secondary malaria vectors [58]. Similarly, *An. maculipalpis* is almost entirely zoophilic [55]. Although the anopheline mosquitoes trapped during the current study were significantly few, their presence was still important because they are potential disease vectors.

Aedes mosquitoes are daytime biters that prefer breeding in flood waters and awide range of artificial containers. Their peak biting time is early in the morning and just before dark in the evening. According to the WHO [59] Dengue guidelines, *Aedes aegypti* is an effective vector of arboviruses because it is highly anthropophilic, bites frequently, and thrives in close proximity to humans. In the current study, the adult *Aedes aegypti* mosquitoes were all trapped from Donholm site (Fig 1), which had a permanent Donholm swamp nearby with relatively clean stagnant water and a neighboring densely populated area. Although the *Aedes aegypti* species mosquitoes sampled were very few compared to the Culex species, their presence was significant because *Aedes aegypti* is a natural vector for arboviruses responsible for human infections including Dengue fever (DF) and dengue hemorrhagic fever /dengue shock syndrome (DHF/DSS) in humans [60]. *Aedes aegypti* has also been implicated as the primary transmitter of other arboviruses that often evoke fear and anxiety wherever reported. These arboviruses include the yellow fever virus (YFV) and zika virus (ZIKAV). Presence of *Aedes aegypti* implies the likelihood of viral transmission in the study area in case the mosquito population increases and by chance gets exposed to viral sources. It was also noted from the current study that 94% of the adult mosquitoes trapped using CDC light traps baited with dry ice were females while the remaining 6% were males. This was in line with a study by Chen and others [61] in which significantly more female mosquitoes were collected compared to males using CO_2 – baited traps. Female mosquitoes are able to perceive CO_2 baited traps because the vertebrate hosts from which they suck blood, release CO_2 which often attracts them.

Nairobi industrial area, where the current study was carried out, is a busy part of Nairobi City with a lot of human movement during the day and it contributes significantly to the economic growth of Kenya. It is characterized by a large number of people working as casual laborers and permanent jobs in the industries, construction sites, garages, commercial premises, and various small scale businesses. The informal settlements around and within Nairobi industrial area has attracted huge low economic population cadre who derive their livelihoods from it. The drainage system in the study area was observed to be relatively poor with evidences of broken sewage pipes emptying combined sewage overflow into the open waste channels some of which were clogged with solid wastes and overgrown vegetation. Municipal solid wastes that mainly comprised of trash especially near the densely populated areas were also evident. The high population, increased individual movements, urbanization, limited financial resources and presence of mosquito vectors can significantly enhance the emergence and re-emergence of arboviruses related human diseases [62]. Poor solid wastes management, poorly managed vegetation, clogged open water channels and congested buildings may also exacerbate mosquito borne human diseases.

Conclusions

A total of 13 mosquito species were identified using their morphological features, and the majority of which were of the genus Culex. The most abundant adult and larval urban mosquitoes obtained from Nairobi industrial area in Kenya, were of the species *Culex pipiens* constituting about 94% and 99% of the total catch of the adults and larvae respectively. Non culex mosquitoes included *An. squamosus, An. maculipalpis,* and *Aedes aegypti*. These mosquito species have the potential of spreading emerging and re-emerging arboviral human diseases putting in mind that the current global climate change may enhance the survival and multiplication of the viruses and their vectors. Therefore there is need for researchers to establish whether these mosquitoes are infected with viruses or not and move on to design effective strategies and formulate policies of reducing the breeding of these mosquitoes in the study area. The bio-control of medically important mosquito vectors using the Toxorhynchites mosquito larvae should be researched further.

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Author's contributions

The research was designed by GK, LK, VN, FN, FM and MK. Collection of mosquito samples and their preservation was done by GK, LK, DB, and RL. DB and

RL identified the mosquitoes microscopically. Data analysis and presentation was carried out by GK, VN and AW. The manuscript was written by GK. All the authors read, reviewed and approved the final manuscript.

Competing Interests

The authors declare that they are no competing interests that exist.

List of Abbreviations

CDC: Centers for Disease Control and prevention;

DF: Dengue Fever;

DHF/DSS: Dengue hemorrhagic fever/dengue shock syndrome

NACOSTI: National Commission for Science, Technology and Innovation

RVF: Rift Valley fever;

RVFV: Rift Valley fever Virus;

UK: United Kingdom

WHO: World Health Organization;

WNF: West Nile fever;

YFV: Yellow Fever Virus;

ZIKAV: Zika virus

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