Aedes aegypti breeding site typology and their productivity in the context of re-emergence of dengue in Ouagadougou, the capital city of Burkina Faso

Hyacinthe Kobié TOE[1,2*], Inoussa TOE[1,3], Moussa Wandaogo GUELBEOGO[1 2], Soumanaba ZONGO[1,3], Idrissa TRAORE[1], Jean-Claude Wilfried Wendnin-my DAMIBA[1], Siaka DEDE[1], Ibrahim SANGARE[3]

Résumé

La dengue a réémergé ces dernières années au Burkina Faso, et la capitale Ouagadougou en est la zone la plus affectée. En l'absence de vaccin et de traitement efficaces, la lutte contre le vecteur *Aedes* par la gestion des gîtes larvaires reste l'une des principales stratégies durables pour faire face aux épidémies de dengue. Cette étude vise à déterminer la typologie et les principaux récipients d'eau propices au développement des larves de *Aedes* dans la ville de Ouagadougou.

Au total, 240 concessions des arrondissements de Bogodogo et de Nongr-Massom ont été visitées entre août et novembre 2021. Tous les récipients contenant de l'eau ont été inspectés, caractérisés, et les stades immatures ont été collectés. Les indices stegomyia ont été estimés et la typologie et la productivité des gîtes larvaires ont été évaluées.

Aedes aegypti (>99%) était l'espèce prédominante et colonisait divers types de récipients d'eau. Toutefois, les récipients abandonnés et les pneus de voiture étaient les gîtes les plus prédominants et les plus productifs ($p < 0,001$). Les principaux indices de risque entomologique (indice de Breteau, indice de récipients et indice de maison) étaient tous supérieurs aux valeurs seuils de l'OMS pendant la période d'étude.

Ces résultats soulignent le risque entomologique élevé de transmission de la dengue et d'autres arboviroses ; mettant en évidence les pneus de voiture et les récipients abandonnés comme les principaux gîtes larvaires à cibler dans la mise en œuvre d'une stratégie durable de lutte contre les arboviroses au Burkina Faso.

Mots clés : *Aedes aegypti*, gîtes larvaires, indices stegomyia, dengue, Ouagadougou

[1] Centre National de Recherche et de Formation sur le Paludisme (CNRFP), Ouagadougou, Burkina Faso

[2] Laboratoire d'Entomologie Fondamentale et Appliquée (LELA), Université Joseph Ki-Zerbo, Ouagadougou, Burkina Faso

[3] Université Nazi Boni, Burkina Faso

***Corresponding author:** Dr Hyacinthe K. Toé, Email: toe_kob@yahoo.fr, hyacinthe.toe@ujkz.bf ORCID: https://orcid.org/0000-0002-3212-5903

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Typologie des gîtes de reproduction de *Aedes aegypti* et leur productivité dans le contexte de réémergence de la dengue dans la ville de Ouagadougou, capitale du Burkina Faso.

Abstract

Dengue has re-emerged in recent years in Burkina Faso, and the capital city Ouagadougou is the most affected city. In the absence of an effective vaccine and treatment, control of the *Aedes* vector through larval source management remains one of the key sustainable strategies for responding to dengue outbreaks. This study aims to determine the typology and keys *Aedes* immature productive water-holding containers in the city of Ouagadougou.

A total of 240 households in the health districts of Bogodogo and Nongr-Massom were visited during the period from August to November 2021 and all the water-holding containers were inspected, characterised, and immature stages were collected. The stegomyia indices were estimated, and larval breeding sites typology and productivity were assessed.

Aedes aegypti (>99%) was the predominant species and colonised various types of water-holding containers. However discarded containers and car tyres represented the most abundant and productive breeding sites ($p < 0.001$). The main entomological risk indices, the Breteau index, container index and house index were all above WHO threshold values during the study period.

These findings underscore the high entomological risk of dengue and other arboviral diseases transmission and highlight car tyres and discarded containers as key breeding sites to be targeted in the implementation of a sustainable arboviral disease control strategy in Burkina Faso.

Key words: *Aedes aegypti*, key breeding, stegomyia indices, dengue, Ouagadougou

Introduction

Dengue and other arboviral diseases have re-emerged globally over the last decade. In 2024, more than 14.4 million dengue cases were reported, causing 11,177 deaths (1) In 2023, seven arboviruses were responsible for a total of twenty-nine outbreaks across twenty-five African countries, of which twenty-two occurred in West Africa. These outbreaks accounted for 19,569 confirmed cases and 820 deaths (2). Burkina Faso experienced its worst dengue epidemic in 2023 with 160,751 suspected cases and 724 deaths reported (3). More than 56 % of cases and 42% of deaths occurred in Ouagadougou centre region. *Aedes aegypti* and *Aedes albopictus* are the main dengue and arboviruses vectors in West Africa (4). In Burkina Faso, *Ae. aegypti* is found as predominant *Aedes* genus species (5, 6).

The control of arboviruses vectors targets both immature and adult stages. Larval control is essentially made through larval sources management (LSM). This can be done through environmental management or chemical control (7). *Aedes aegypti* is known to colonize diverse types of water-holding containers (8). Understanding the larval ecology, especially the characteristics and typology of *Aedes* colonized water-holding containers, is crucial for implementing a sustainable LSM strategy. Overall, in Sub-Saharan Africa used car tyres are found playing a key role in *Aedes aegypti* larval ecology, as reported to be the predominantly colonized breeding sites with high larvae and pupae productivity (9-12). In addition to car tyres, discarded containers constitute some of the most common and productive mosquito breeding sites (13-15). In a Peri-urban setting with insufficient coverage in piped water, storage containers such as drum/barrel and terracotta jars have played important role in *Aedes* mosquito proliferation (16, 17). In Burkina Faso, particularly in the city of Ouagadougou, larval habitats such as waste car tyres, animal feeding pot, and water storage containers are the most common and the most contributors to *Aedes* immature stages productivity (5, 6, 18).

The presence of immature stages in water holding containers is used to estimate the stegomyia indices (19). These indices are used to assess the household's infestation level and to predict the entomological risk of dengue and other arboviral diseases. Although the shortcomings of these indices in capturing dengue transmission risk are widely recognized, they still provide valuable information for assessing breeding-site abundance (20, 21). In Burkina Faso, the house index, container index and Breteau index are reported to exceed the threshold risk criteria particularly during the rainy season (5, 18). Ouagadougou, the capital and the biggest city of the country, more than the other cities, faces an incredible high dengue case and should requires particular attention. This study aims to determine the water-holding container typology, their productivity and assess the stegomyia indices of dengue risk transmission in the city of Ouagadougou.

I. Material and methods

I.1. Study site

This study was carried out in Ouagadougou city (12° 21' 56.4" North, 1° 32' 2" West) between August and November 2021, corresponding to the high dengue transmission period. Ouagadougou is capital and largest city of Burkina Faso with 2,415 155 inhabitants (22), accounting for most dengue cases. For instance, 75.9% of the 8359 national dengue cases occurred in Ouagadougou in 2021 (23). The climate is Sudano-

Sahelian with an average annual rainfall of 400-800 mm. The study was carried out in the administration district of Nongr-Massom (district 04) and Bogodogo (district 05). In Nongr-Massom, mosquito larval collections were performed in the quarters of Kossodo, Toubdouweogo, Paspanga, Nioko, Tanghin, and Dapoya (figure 1). While in Bogodogo, mosquito larval sampling was conducted in Zogona, Kalgondin, Silmissin and Dagneon (figure 1). In each district, larval survey study took place in 30 households per month randomly selected in the field. The minimum distance required between households was 40 meters. The field technicians were assisted by local guides to easy the access to the households. A total of 240 households were visited, with 120 households surveyed in each district over the four-month study period.

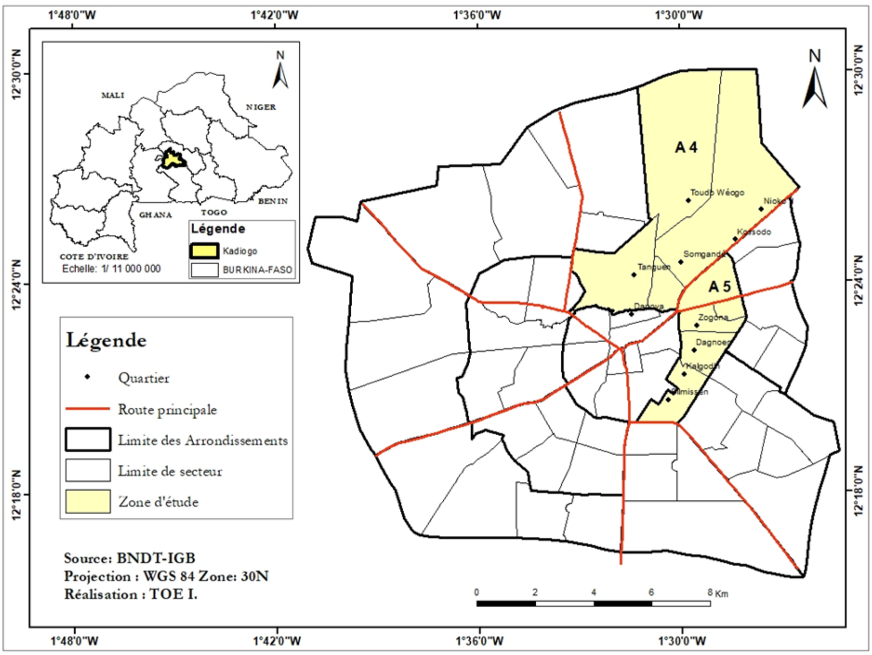

Figure 1: Map of Ouagadougou showing the study sites

I.2. Larval sampling

The selected households were visited monthly. In each concession, a thorough inspection of the intra and peri-domestic areas for water-holding was performed. Larvae and pupae were sampled in positive containers and brought to the laboratory. A container was considered positive for *Aedes* when one or more larvae or pupae of *Aedes* mosquitoes were present (24), while a positive household was one with at least one positive container. The information was collected via the ODK (Open Data Kit) collect application configured in a tablet. Larval specimens were sorted by distinguishing *Aedes* larvae from those of other genera, including *Anopheles* and *Culex* using morphological identification keys (25, 26). Only *Aedes* larvae and pupae were reared to the adult stage under controlled conditions of temperature (27 ± 2°C) and relative humidity (75± 10%) by providing cat food pellets as a nutritional source. The adults were identified under binocular stereo microscope using morphological identification keys (27). The water holding-containers were classified as 1) animal drinking pots: includes all type of containers used to provide water to animal; 2) car tyres: for used tyres; 3) discarded containers: refers to all type of discarded containers such as cans, bottles, buckets, unused containers; 4) natural/puddles, 5): plants/flowers vases; 6) terracotta jars; 7) Water storage containers: includes drum, barrels and type of containers used for water storage; 8) other: for container cannot classified in any the category.

The database from these larval surveys was used first to identify the most productive habitats and then to calculate the entomological risk indices, namely the stegomyia indices.

I.3. Statistical analysis

The traditional *Stegomyia* indices, such as the Breteau index (BI, number of the positive containers per hundred houses), the container index (CI, percentage of water holding containers infested with larvae or pupae), and the house index (HI, percentage of houses infected with larvae and/or pupae) were estimated (28). A house index (HI) greater than 5%, a Breteau index (BI) exceeding 20, and a container index (CI) greater than 5% were considered as a threshold for indicating a dengue-sensitive area (28). These indices were compared between districts and months of collection using ANOVA test. Larval and pupal productivity was estimated for each category of water-holding container and comparing using ANOVA test. All the analyses were performed using R software version 4.5.0.

II. Results

II.1. Water-holding containers typology and productivity

A total of 250 water-holding containers were recorded during the study. Discarded containers were the most represented 28.4% (71/250). Terracotta jars and car tyres were the second and third most abundant containers with 19.2 % (48/250) and 18.0 % (45/250) respectively (Table 1). These three types of water-holding containers account for 67.4 % of all the containers recorded. Other types of containers, such as water storage containers (17.2%) and animal drinking pots (9.2%), were also among the most common breeding sites.

Out of the 250, 168 were positive (67.2%) for *Aedes* immature stages (larvae and/or pupae). Among the positive containers, the most common types were discarded containers (33.3%), car tyres (23.8%) and terracotta jars (16.7%). In addition to these container types, water storage containers accounted for 10.1% of the positive containers. Each of the remaining container types contributed less than 10% of the positive containers (Table 1).

Table I: typology of water holding containers and their larval/pupal productivity

Water-holding containers type	No. of containers (%)	No. of positive containers (%)	No. of larvae (%)	No. of pupae (%)
Animal drinking pots	24 (9.6)	13 (7.7)	786 (6.2)	70 (4.4)
Other	10 (4.0)	8 (4.8)	516 (4.1)	49 (3.1)
Terracotta jars	**48 (19.2)**	**28 (16.7)**	**2407 (19.0)**	204 (12.9)
Natural/puddles	6 (2.4)	4 (2.4)	131 (1.0)	**212 (13.4)**
Car tyres	**45 (18.0)**	**40 (23.8)**	**3049 (24.0)**	**315 (19.9)**
Plants/flowers vases	3 (1.2)	2 (1.2)	616 (4.9)	95 (6.0)
Discarded containers	**71 (28.4)**	**56 (33.3)**	**4339 (34.5)**	**546 (34.5)**
Water storage containers	43 (17.2)	17 (10.1)	844 (6.7)	91 (5.8)

In bold, the top three containers for each category, No: number

II.2. Containers larval and pupal productivity

A total of 12,688 *Aedes* larvae and 1582 pupae were collected. Overall, discarded containers (34.5%), car tyres (24.0%) and terracotta jars (19.0%) contributed for 77.5% of the total larvae collected (Table 1). Natural/puddles were the container type less contributed to the larval productivity. The abundance of larvae significantly differed between container types (df = 7, $p = 0.001$).

For pupae, a total of 1582 was collected. Pupal productivity significantly varied according to the container types (df=7, $p < 0.001$). The top two most common containers contributed to pupae productivity were discarded containers (34.5%) and car tyres (19.9%). These two container types contributed to more than 54% of the total pupae productivity. Two other container types, such as natural/puddles and terracotta jars accounted for 13.4% and 12.9 % respectively (Table 1).

II.3. Stegomyia indices of entomological risk assessment

Entomological risk was assessed using the traditional Stegomyia indices, namely the House Index (HI), Container Index (CI), and Breteau Index (BI).

House Index (HI)

A total of 240 households were visited and 97 were found with at least one positive water-holding container suggesting an overall mean HI of 40.4%. The HI ranging from 13.3% to 66.7% and from 0.0% to 50.0% respectively in Bogodogo and Nongr-Massom. The HI was found to vary significantly across months and districts ($p < 0.001$) and exceeded the dengue transmission risk threshold (HI > 5%) throughout the study period except in November in Nongr-Massom (figure 2). The lowest HI was observed in November, specifically in Nongr-Massom, where no positive container was found. The highest HI was observed in September and October in Bogodogo with respectively 66.7% and 63.3% (figure 2).

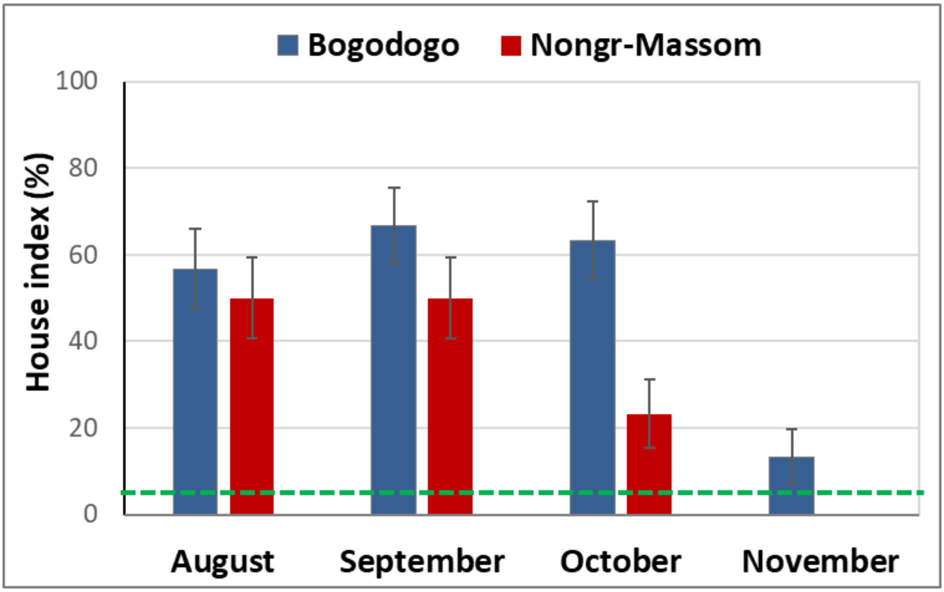

Figure 2: House index (HI) from August to November in Bogodogo and Nongr-Massom. The green dotted line indicates the threshold of 5% for entomological risk of dengue

Container index (CI)

Overall, out of the 250-water holding-containers recorded, 168 were found with *Aedes* larvae/pupae with an overall CI of 67.2% (table 2). The CI ranging from 36.4% to 83.3% and from 3.0% to 82.0% respectively in Bogodogo and Nongr-Massom. The Container Index (CI) exceeded the WHO threshold (>20%) from August to November, excepted in Nongr-Massom in November, where a CI of 3% was obtained (figure 3). The overall CI varied significantly between months (F=7.76, $p = 0.038$) but not between district (F=3.74, $p = 0.37$).

Table II: Number of water-holding containers inspected and number of positive per month in Bogodogo and Nongr-Massom

	Month	No of containers	No of positive containers
Bogodogo	August	41	27
	September	36	28
	October	42	35
	November	11	4
Nongr-Massom	August	39	32
	September	32	30
	October	16	11
	November	33	1

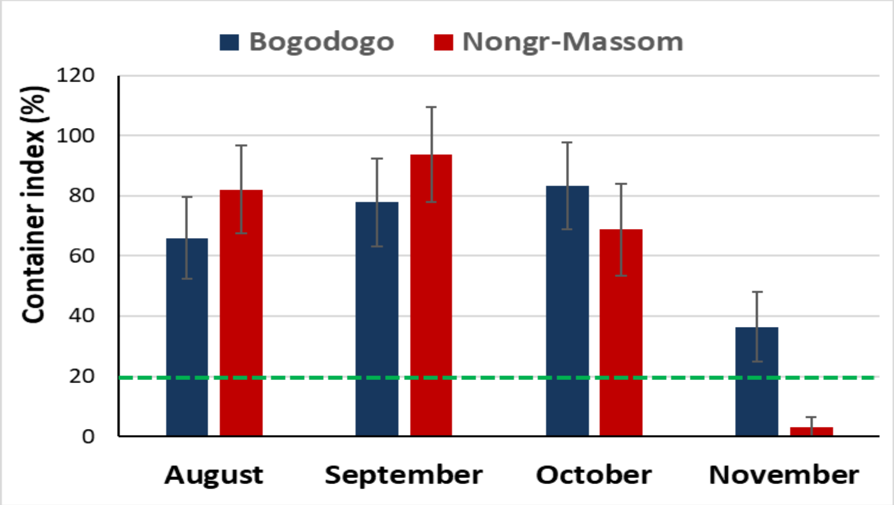

Figure 3: Container index (CI) from August to November in Bogodogo and Nongr-Massom. The green line indicates the threshold of 20%, for the high entomological risk of dengue

Breteau index (BI)

A BI range from 13.3 to 116 and from 3.3 to 106.7 respectively in Bogodogo and Nongr-Masson. The highest BI was observed in October in Bogodogo while the lowest in November in Nongr-Massom. Overall, the BI was over the threshold of 5 in the two districts and months except in November in Nongr-Massom, where a BI of 3.3 was obtained (figure 4). Statistical tests showed that the value of the BI varied significantly according to the period for the Breteau index (F=8390.1; p < 0.001) and district (F=14630; p < 0.001),

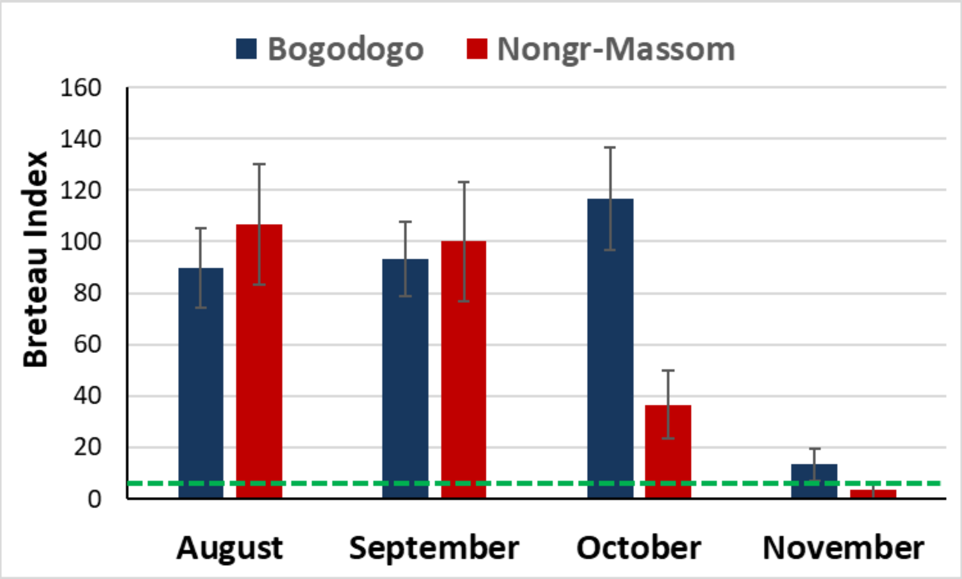

Figure 4: Breteau index (BI) from August to November in Bogodogo and Nongr-Massom. The green dotted line indicates the threshold of 5, for the entomological risk of dengue

III. Discussion

Burkina Faso is currently experiencing dengue outbreaks, and Ouagadougou be the most affected city. The study was performed during the rainy season to specifically cover the period of high dengue transmission. We reported a predominance discarded cars tyres which constituted most immature productive breeding sites for *Aedes aegypti* mosquitoes. Indeed, Burkina Faso is enclosed mainly depending on road transportation. Millions of second-hand cars tyres are imported. These used tyres are cheaper than the new ones and are considered as an opportunity for people with limited budgets. In addition to their overall availability, tyres offer an ideal condition for oviposition and larvae growing to adult's mosquito. Indeed, tyres are made with non-biodegradable material able to support mosquito breeding (29). The dark colour of tyres' heat-retaining properties could make them more attractive and suitable for many mosquito species (30). Previous studies in Ouagadougou (5, 18), Bobo-Dioulasso, Banfora, and Boromo (6) reported tyres as the common and productive breeding sites for *Aedes aegypti*. The discarded containers found mainly in peri-domestic settings contribute to the *Aedes* mosquito abundance in Ouagadougou. These unused containers are most often human-made, and their availability may increase with urbanisation. Such containers, which accumulate rainwater despite having no immediate purpose, provide optimal conditions for mosquito breeding (31). In the neighbouring country such as Côte d'Ivoire, discarded containers have been reported to play a key role in *Aedes* mosquito proliferation (32). The storage of water in large containers, particularly in peri-domestic areas, may pose a significant risk for mosquito proliferation if these containers are not properly covered, as reported here. The water storage, although useful, may constitute a risk of *Aedes* proliferation as similarly reported in Abidjan in Côte d'Ivoire (16).

We reported that all three stegomyia indices exceeded the WHO threshold criteria high risk level of dengue during the study period. These high indices suggest a high infection of households with *Aedes* immature positive containers. The high infection rate of breeding sites with immature stage could contribute to the increase of adult mosquito abundance. Previous study in Ouagadougou reported high stegomyia indices; however, these were not reliable indicators of adult abundance (5). Characterizing breeding site typology and the key productive containers is essential for implementing tailored community-based interventions , which have already shown promising results in reducing mosquito biting exposure and pupal index in Ouagadougou (33).

Conclusion

The entomological investigation conducted in Ouagadougou city confirmed that discarded used car tyres and water-holding containers are the most common and significant contributors to *Aedes aegypti* proliferation. This study once again highlights the problems of solid waste management in cities of Sub-Saharan African countries. To reduce the burden of dengue and arboviral diseases, a sustainable, multi-sectorial strategy including communities, municipalities, and politics makers is required. Research toward the management and the recycling of the solid wastes should contribute to these solid waste disposals and improve population wellbeing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Author's contribution

HKT, SD, MWG: conception and design of study**; IT, SZ, IT, JCWWD:** sampling and data collection**; HKT, IT, SZ:** analysis and interpretation of data**, MWG, IS:** supervision and validation; **HKT, IT:** drafting the first draft of manuscript: **HKT, IT, SZ, MWG, SD and IS r**evising it critically for important intellectual content, **All the authors:** final approval of the version to be submitted

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Ethical considerations

The study received approval from both the CNRFP institutional ethical committee and ethical committee for health research (*Comité d'éthique pour la Recherche en Santé, CERS*) of the Ministry of Health under deliberation number CERS deliberation no. 2020_07_122. Signed informed consent was obtained from household heads prior to larval survey and collection. The team worked with local guide to easy the access to the population and get into their households.

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