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## Household water storage containers: *Aedes aegypti* larval breeding site and high risk of transmission of arboviruses in Abidjan, Côte d'Ivoire

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### ABSTRACT

Dengue 3 epidemic was declared in Abidjan in 2018. Vector control was directed towards management of breeding sites to reduce proliferation of mosquitoes. Thus, characterization was carried out through larval prospecting in 100 households in six communes of Abidjan in February and August (large and small dry season) of 2018, before and after mosquito control. 3,809 larval breeding sites were inventoried, including 2,289 before and 1,520 after (p-value > 0.05). 76% of sites (2,909), consisted of water storage (1,380) and abandoned containers (1,529). These two categories were most abundant in households (p-value < 0.0001). Greatest number of storage containers were observed in Attécoubé (n = 312) and Abobo (n = 296). Abandoned containers were abundant in Port-Bouet (n = 416). Number of abandoned containers was reduced from 1,016 before to 513 after operation (p-value < 0.01). However, water storage containers have increased slightly. It went from 686 before operation to 694 after. Positive storage containers (255) were also the most numerous (53%). Their proportions were 151 (41%) and 104 (55%) before and after mosquito control. They were very productive in *Aedes aegypti*. Household water storage containers could lead to reconstitution, maintenance of mosquitoes and increased risk of arboviruses spread in Abidjan.

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**Keywords:** larval breeding sites, urban, mosquito control, spread, arboviruses

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## INTRODUCTION

Water plays a key role in the development of different sectors of a country's economy (Arifi et al., 2019). Urban demand affects water supply. Currently, water scarcity is a central concern for many cities. In Abidjan, with rapid population growth, urbanization and economic development (Ahadji-Dabla et al. 2019), demand for water among populations is growing (Atta et al., 2013; Tia and Séka, 2015). The lack of water leads the inhabitants to save this precious resource (Kouakou et al., 2012). For example, many households, whether connected to the drinking water system or not, use storage (Désille, 2012). While home water storage is ultimately extremely common, its practice is nevertheless associated with often high health risks, especially vector-borne diseases (Handschumacher et al., 2019). Storage containers, which do not close or have no cover, allow contacts between the stored water and the mosquitoes, thus promoting their proliferation and sedentarization (Darriet, 2014).

Mosquitoes, which are responsible for the majority of parasitic and viral diseases (yellow fever and dengue) cause more than one million deaths worldwide each year (WHO, 2016). Dengue fever alone is estimated to affect nearly 400 million people worldwide annually (Bhatt et al., 2013). The risk of epidemic outbreaks can be due to local environmental (Failloux & Moutailler, 2015) and social factors (Daudé et al., 2015) that can lead to the proliferation of these vectors during the seasons. Indeed, *Aedes aegypti*, major vector of arboviruses is characterized by a strong adaptation to the urban environment and its high rate of anthrophilia (Failloux and Hervé, 2003). Since 2010, recurring cases of arbovirolosis, including dengue appear in Abidjan (Koné et al., 2018). In the absence of vaccines available in Côte d'Ivoire, the means of control of these diseases transmitted by *Aedes aegypti* rely mainly on surveillance and protective measures against this vector (WHO, 2012; Gubler, 2011). In addition, Saliha et al. (2018) reported that elimination or reduction of larval breeding sites is the most effective approach to mosquito control. For example, the most commonly used control measures in Côte

d'Ivoire include not only the removal of larval breeding sites, but also the removal of adult mosquitoes through fumigation and application of insecticides. Despite all these vector control efforts, these mosquitoes continue to proliferate in our cities and especially in Abidjan. What are the environmental factors responsible for keeping mosquitoes? It is to address this concern that this study was carried out in 6 communes of Abidjan. The aim of the survey was to make an inventory of the larval breeding sites before and after a mosquito control operation in order to better understand the spread of mosquitoes despite the implementation of control measures in Abidjan.

## MATERIALS AND METHODES

### Survey area

Abidjan is located in the south of Côte d'Ivoire, on the edge of the Gulf of Guinea and crossed by the Lagoon Ébrié (Figure 1). The city of Abidjan covers an area of 422 km<sup>2</sup>. Ivorian economic capital, its population was estimated in 2014 to 4707,000 inhabitants or 21% of the country's population. Abidjan is experiencing strong growth characterized by strong industrialization and rampant urbanization.

The climate is sub-equatorial, hot and humid. It includes a large rainy season (May-June-July), a small rainy season (September-November) and two dry seasons. The great dry season begins in December and ends in late March. Rainfall is abundant and reaches more than 1500 mm of water per year. The temperature is almost always around 27°C and the average annual humidity is above 80%. Abidjan is divided into two parts: North Abidjan and South Abidjan; located on both sides of the Laguna Ébrié (Figure 1). This study was carried out in 6 communes, four of which were in North Abidjan (Abobo, Yopougon, Attécoubé and Cocody) and two in South Abidjan (Koumassi and Port-Bouet) (Figure 1).

### Larval prospecting

The surveys were carried out in 100 randomly selected households in each of the 6 municipalities (Figure 1). In the field, larval

surveys were carried out on foot through the districts of the different communes. But before that, each head of family or any person in whom larvae were sought, gave his or her consent orally with full knowledge of the facts. In each concession where the team prospected it has also been explained to the head of the family or his or her legal representative(s) what the reason for this investigation is, how the team will proceed to conduct the various activities.

After the consent and authorization of the family member, all artificial and natural water receptacles in the yard were inspected. Any container that contained at least one larva or nymph (or even an exuvia) was considered positive (WHO, 2014) and a sample of larvae or nymphs was collected and kept alive in pots containing water from the larval breeding site. Each pot was carefully labelled with the date of collection, the identification number of the dwelling, the type of larval breeding site, etc. The larvae and nymphs collected in the field were returned to the NIPH insectarium in plastic jars. They were then put in cages. These cages were inspected daily to suck adults to identify them.

### Estimation of transmission risk indices

The following indices were estimated. Those are:

**The Breteau index (BI):** this is the number of containers containing larvae or nymphs per 100 dwellings inspected.

**BI** = (number of positives containers for *Aedes aegypti* x 100)/number of houses visited

**The Container index (CI):** this is the percentage of positive containers.

**CI** = (number of positives containers for *Aedes aegypti* x 100)/number of water containers)

**The housing index (HI):** this is the percentage of houses where larvae or nymphs have been found. **HI** = (number of houses with at least one positive breeding site for *Aedes aegypti* x 100)/number of houses visited.

### Data analysis

Excel software was used for data entry and data analysis was done with XLSTAT software. The numbers were compared using one-way analysis of variance (ANOVA) with a significance level of 5%, as well as the proportions using the Chi-square test. A p-value < 0.05 was considered statistically significant.

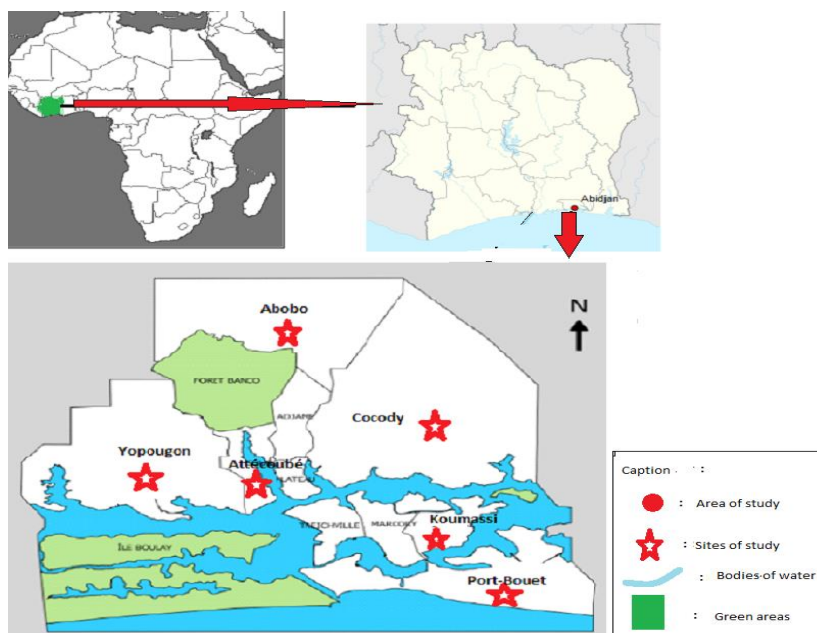


Figure 1: Location of study area and sites.

## RESULTS

### Inventory of mosquito larval breeding sites

Larval surveys were carried out in 1200 households, or 600; before and after mosquito control, at the rate of 100 households per municipality. In 143 households, no larval breeding sites were observed, a proportion of 11.9%. This proportion was 11.3%, or 68 households in the first survey before the mosquito control and 78 households, or 12.5% after this operation. In the other households, 3809 larval breeding sites were counted in all the localities surveyed. Prior to mosquito control, 2,289 larval breeding sites were counted, or 60%. After this, 1,520 site were inventoried, or 40% of the total. The variance analysis yielded a significant difference ( $p < 0.05$ ), with the greatest number of larval breeding sites recorded prior to the mosquito control operation. The surveyed larval breeding sites were grouped according to their characteristics into 5 classes. These are: other types of sites, natural sites, tires, abandoned containers and household water storage containers (Figure 2). Abundance varies depending on the type of larval breeding site. Abandoned and water storage containers were the most abundant ( $p < 0.001$ ). But Fischer's post-hoc test reveals that there is no significant difference between storage containers and abandoned ones. Before the operation, 1,016 abandoned containers were counted, or 44% of the larval breeding sites. They were the most numerous of all the classes of sites ( $p$ -value  $< 0,001$ ). However, after mosquito control, the number of abandoned containers decreased ( $N = 513$ , or 34%). As for water storage containers in households, the number before was 686, or 30%. After mosquito control, this number increased to 694, or 46% of the larval breeding sites found. The number of water storage containers increased slightly. Nevertheless, a slight decrease in the total number of larval breeding sites was observed after vector

control. However, larval breeding sites are still present in the different households ( $N = 1520$ ), mainly domestic water storage containers ( $N = 694$ ). Drinking water storage containers were the most abundant in most of the towns surveyed. The largest number ( $N = 175$ , or 26%) was counted in Abobo, while 73, or 11% was counted in Cocody; before the mosquito control ( $p$ -value = 0,001). After mosquito control, 164 water storage containers, or 24% were counted in Attécoubé and 90 or 13% were found in Port-Bouet ( $p$ -value = 0,001). As for the abandoned containers, 311, or 31% were obtained in the commune of Yopougon, against 79 (8%) in Attécoubé before the mosquito control. After this operation, 151 abandoned containers, or 29% were counted in the commune of Port-Bouet, against 39 (8%) in Yopougon.

### Distribution of positive sites in *Aedes* in all municipalities

A total of 561 pre-and post-release larval breeding sites contained at least one *Aedes* mosquito larva, or 14.73% of the 3809 obtained larval breeding sites. Among positive larval site, there was a predominance of water storage containers and abandoned containers with numbers of 255 (45%) and 205 (37%) respectively (Figure 3). Abandoned and water storage containers were the most positive among the listed sites ( $p < 0.05$ ). The tires were also colonized by mosquitoes, where 53, or 9% contained larvae. Prior to mosquito control, larval surveys were conducted and 371 positive larval sites were found, including 143 abandoned containers, 39% and 151 storage containers, 41%. After the mosquito control operation, the assessment resulted in 190 positive larval sites, of which 63 containers were abandoned, or 33% and 104 storage containers, 55%. These results showed a significant reduction in the number of positive larval breeding sites before and after this

operation (Figure 3). Nevertheless, some positive larval sites such as drinking water storage containers are still present in households. The water storage containers were also the most colonized by mosquito larvae. As for used tires, with 10.2% before mosquito control, the proportion of tires containing mosquito larvae has decreased and is 8%.

#### **Productivity of larval breeding sites types positive for *Aedes aegypti***

The total number of larvae counted in positive larval breeding sites was 20094 prior to mosquito control. After this operation, a total of 9988 larvae were obtained. The difference is significant ( $p < 0.01$ ). Household water storage containers were the most colonized and positive larval sites among the inventoried sites before and after the vector control operation (Figure 4). But it was the tyres that were the most productive before the mosquito control of the city of Abidjan. On average, 99 larvae of *Aedes* mosquitoes were counted per tyre (Figure 4). After this operation, the abandoned and storage containers were the most productive with 59 and 53 larvae per larval breeding sites, respectively.

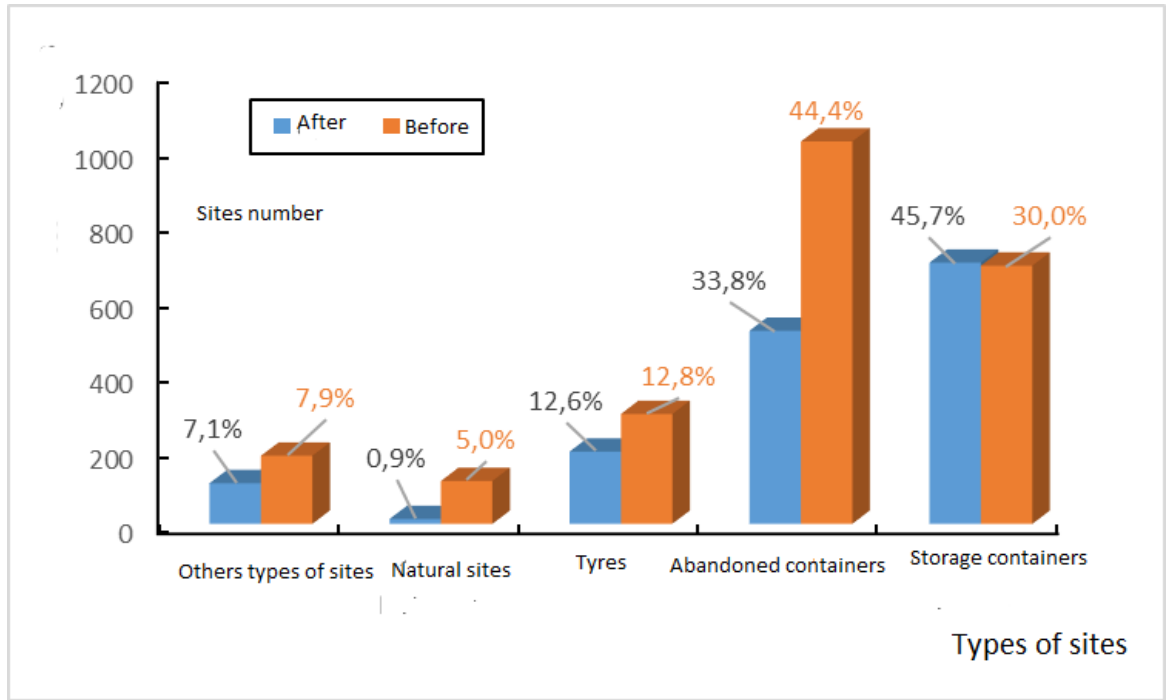
#### **Stegomyens indices and risk of transmission of arboviruses**

The values of the Stegomyens indices calculated before and after the mosquito control varied from one municipality to another in Abidjan city. Thus, the number of households with a positive site; expressed by the house index varied between 21% in

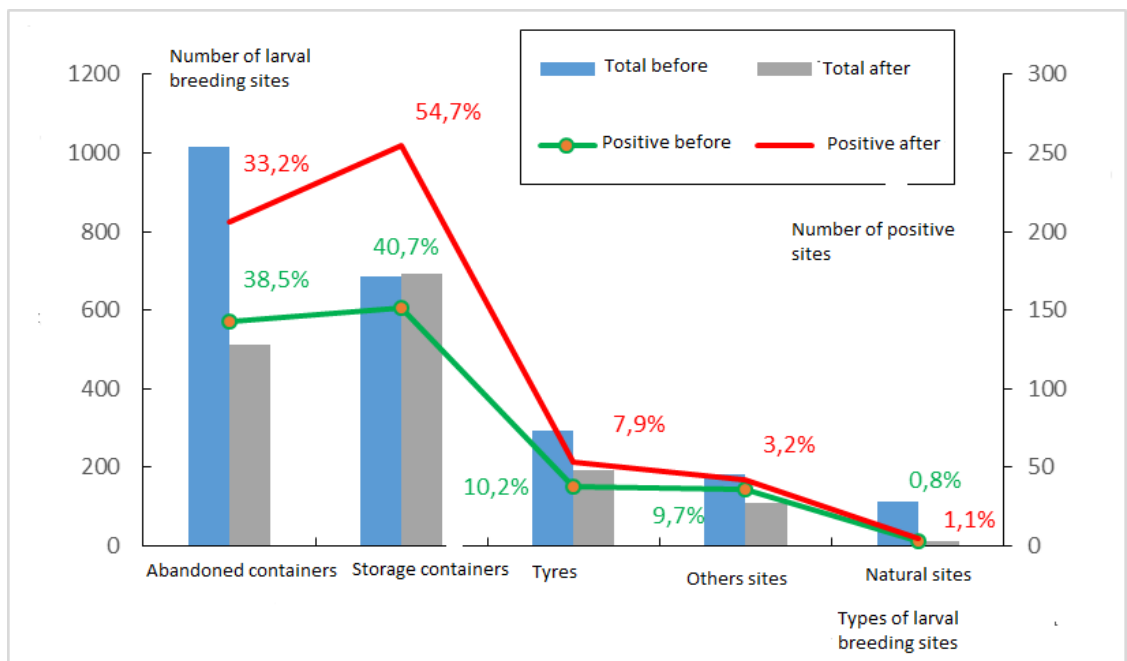
Yopougon to 52% in the municipality of Koumassi. This number of larval breeding sites present in the dwellings decreased considerably in all communes after mosquito control (Table 1). This decrease was the largest in the municipalities of Attécoubé and Koumassi, with 11 and 18% respectively (Table 1). As for the number of positive containers, it also varied between 6% in Yopougon and 29% in the municipality of Koumassi. Before mosquito control, the container index in all municipalities was greater than 2. After the operation the container index increased in the municipality of Yopougon (17%). In contrast, in the other municipalities this index fell, this decrease was remarkable in the municipality of Attécoubé where the container index went from 17 to 6%. However, the risk still exists as the container index is greater than 2. As for the Breteau index, the observed values are between 29% in Yopougon and 83% in Koumassi.

These values are above 5% in all municipalities and also above 35%. This index also decreased after mosquito control, but nevertheless remains above the thresholds and therefore the risk is still present (Table 1).

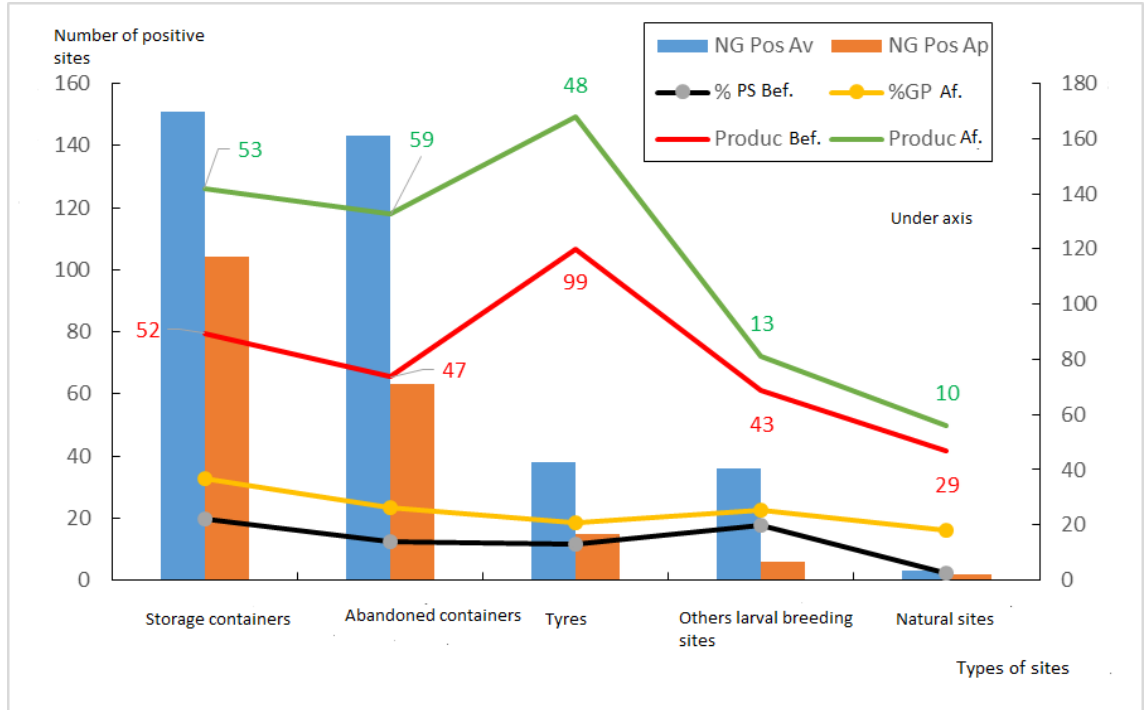
Larval evidence found has densities between 4 and 7 prior to mosquito control. These densities were significant in the communes of Koumassi and Cocody, with values of 7 and 6 respectively. After mosquito control, these values decreased and lie between 3 and 5. This decrease was significant in the communes of Attécoubé and Koumassi, with values of 3 and 4 respectively. These thresholds are found to be less than 6 (Table 1) after mosquito control.



**Figure 2:** Number of larval breeding sites counted before and after vector control operation.



**Figure 3:** Proportion of positive breeding sites before and after mosquito control in the 6 municipalities of Abidjan.



**Figure 4:** Most productive breeding sites of *Aedes aegypti* before and after vector control. NB. NG Pos Av = Number of positives breeding sites before ; NG Pos Ap = Number of positives breeding sites after ; Produc bef = productivity before and Af = after, GP = breeding sites after ; PS Bef = breeding sites positive before.

**Table 1:** Stegomyen indices and density of *Aedes aegypti* larvae found in dwellings before and after mosquito control in 6 communes.

Communes	Houses visited	Positive sites houses		Total larval breeding sites		Positive sites		*IM (%)		*IR (%)		*IB (%)		Density scale	
		Bef.	Aft	Bef.	Aft	Bef	Aft	Bef	Aft	Be	Aft	Be	Aft	Bef	*Aft
<b>Abobo</b>	104	<b>38</b>	25	398	280	69	39	37	24	17	14	66	38	<b>5 - 6</b>	<b>4 - 5</b>
<b>Attécoubé</b>	106	<b>40</b>	12	353	288	60	16	38	11	17	6	57	15	<b>5 - 6</b>	<b>3</b>
<b>Cocody</b>	105	<b>49</b>	27	259	253	73	40	47	26	28	16	70	38	<b>6</b>	<b>4 - 5</b>
<b>Koumassi</b>	100	<b>52</b>	18	283	241	83	27	52	18	29	11	83	27	<b>7</b>	<b>4</b>
<b>Port-Bouet</b>	103	<b>31</b>	25	421	293	53	40	30	24	13	14	51	39	<b>4 - 6</b>	<b>4 - 5</b>
<b>Yopougon</b>	112	<b>24</b>	23	575	165	33	28	21	21	6	17	29	25	<b>4 - 5</b>	<b>4 - 5</b>

NB: MI: Housing index; CI: Container index; BI: Breteau index; Bef: before; Aft: after.

## DISCUSSION

Larval surveys conducted during this study showed a high diversity of larval breeding sites colonized by *Aedes aegypti* larvae. The majority of these were created by man (Iro et al., 2020) because of his activities as observed by Tia et al. (2016) and Koumba et al. (2018). Thus, the classification of the larval sites inventoried made it possible to observe that the breeding places of mosquitoes of the genus *Aedes* and especially *Aedes aegypti* in households in Abidjan were made up of water storage containers and abandoned containers. These sites of anthropogenic origin or waste of civilization are partly due to poor environmental management (Lapang et al., 2019) and especially to human negligence (Tia et Ogbapo, 2019). This led Failloux & Moutailler (2015) to affirm that degradations afflicted to the urban environment of developing cities; promote the multiplication of potential larval sites and the proliferation of vectors. Water storage containers are present in all the households visited. And the mismanagement of these leads to their colonization by *Aedes aegypti*. Whatever the time of the larval surveys, there is always water in these containers for the daily domestic activities of humans. During the dry season, when other types of breeding sites are dried, mosquitoes can still access water through storage containers that still contain water. Very often, this water is not well conserved, which allows mosquitoes to lay eggs.

Among the numerous larval sites created by man, the water storage containers in the households were the most abundant, before and after the operation of mosquito control. Our results reflect those found by Sevidzem et al. (2020) which showed in their study in Akanda that the water storage containers were the most numerous. Similarly, Tia et al. (2016) showed that the containers used to conserve water; atypical larval sites of *Anopheles* were the most abundant among the sites created by man. They have also been identified in all municipalities. In fact, the recurring interruptions in the distribution of water cause people to store this essential food in a varied

range of containers in all households. The management of these potential domestic breeding sites is becoming a real problem and a preferred breeding sites for some mosquito species such as *Aedes aegypti* (Handschumacher et al., 2019). It would also pose a risk because this water was conserved for a long time (Koumba et al., 2018; Sy et al., 2016). When water is stored in open or poorly closed reservoirs, they are an ideal habitat for mosquito reproduction. Thus, the high number of water reservoirs could promote the proliferation of mosquitoes in prospected municipalities. Indeed, the massive reduction in the number of abandoned containers, as well as the other types, encouraged the increase of positive sites, especially at the level of drinking water storage containers that remained without any activity in the majority of the households visited. Some populations have not only refused larvicidal treatment of water storage containers containing larvae, but also their elimination during mosquito control. This could contribute to increased mosquito population density and transmission. Indeed, mosquitoes of the genus *Aedes* and especially *Aedes aegypti*, rarely move away from their emergence sites and their flight range is around 100 m. Thus, several generations will emerge from these sites as long as they are in water and the high density of vectors could ensure the transmission of pathogens (Rodhain, 2015).

For example, the abundant production of *Aedes aegypti* in water storage containers that abound in households could increase the risk of transmission of arbovirolosis (Sy et al., 2016).

The water storage containers in the houses were the most colonized by *Aedes aegypti*. Our results corroborate those of Konan et al. (2014) who stated that the water storage containers constituted the majority of the larval sites colonized by *Aedes aegypti* during an entomological survey carried out in Seguella during a yellow fever epidemic. According to Padonou et al. (2020), the proliferation of mosquitoes carrying arboviruses is likely due to a number of factors including the suboptimal water storage practices. Storage containers



productivity could become importante. This is due to the fact that the abandoned containers and tyres that were the most colonized and productive were largely eliminated during the mosquito control. These results are comparable to those of Bagny et al. (2009a), who stated that this species colonizes all types of breeding sites, the most productive of which are voluntary water storage breeding sites. They added that storage containers are abundant in the courtyards of dwellings (Bagny et al., 2009a). Jauze et al. (2010) reported that the average number of larvae produced in storage containers is twice as large as the number of larvae produced by other types of human-produced larval breeding sites. The productivity of different types of larval breeding sites is highly variable. Abandoned containers and tyres can easily be eliminated by a good public awareness campaign and effective physical struggle. They therefore have a very limited importance in the production of larvae. As for the containers for storing drinking water, the struggle becomes difficult because the conservation of water becomes an undeniable necessity; because of the lack of water and untimely cuts. Their filling is often linked to the regime of rains and cuts, but constitute water reserves. They play a key role in the ecology of *Aedes aegypti* (Schmidt et al., 2011; Padonou et al., 2020). It is therefore its conservation that needs to be reviewed so that water stored in homes is not a potential source of mosquito development in our homes (PAHO, 2019). The storage containers were the most colonized before and after mosquito control because of their proximity to humans. Indeed, mosquitoes of the genus *Aedes* prefer colonized larval sites that are located in the immediate environment of man. It is to this end that Atta et al., (2013) even expected an increase in these populations in inhabited areas due to the good adaptation of this species to changes related to urbanization, such as the multiplication of water storage site (Jauze et al., 2010). The domestic containers present before and after the mosquito control in most of the houses of Abidjan constitute the main domestic sites. They probably contribute a

large part to the increase in the number of *Aedes aegypti*. They could pose a serious problem for the eradication work of this species because their destruction depends on the will of the occupants of the houses. Stegomyen indices are subject to significant variations that are dependent not only on the timing of surveys, but also on the human population. Indeed, water management in homes in Abidjan on the one hand and abandoned containers on the other led to a high density and therefore a high risk of epidemic. This finding was also made after the mosquito control where the majority of storage containers that have not been treated or disposed of still abound in all the courtyards visited. The population continued to create larval breeding sites through the release into the environment of objects they no longer use. All these behaviours contribute to increasing and maintaining the risk of spreading arboviruses in Abidjan. Thus, the container and Breteau indices that give threshold values for risk of arbovirolosis outbreaks to predict outbreaks are very high before and after this study (Padonou et al., 2020). The risk of an outbreak of arbovirolosis is therefore very high in Abidjan. The house index was higher than the value of the scale of larval densities; this translates into a very high risk of epidemics (Padonou et al., 2020)

## Conclusion

The present study in the city of Abidjan has shown that the water storage containers in the dwellings of the municipalities are abundant whatever the periods of this study. They provide suitable habitats for the development of the immature stages of *Aedes aegypti*, a major vector of arbovirolosis. The majority of the sites found were created by human populations, either through negligence or ignorance. The massive presence of positive water storage containers in households could increase the risk of spread and epidemics of mosquito-borne pathogens. The predominant role of man in the creation of larval breeding site for *Aedes aegypti* in dwellings requires the need for intensive mass sensitization of the population in all its components to the use of

adequate storage containers by choosing models of containers and devices suitable for preservation. It is also important to increase entomological surveillance and make it permanent in all the municipalities of Abidjan. Mosquito control must also continue by associating the population whose participation is crucial in the control of arboviruses.

### COMPETING INTERESTS

The authors declare that they have no competing interests.

### AUTHORS' CONTRIBUTIONS

FD: drafting and finalization of the manuscript; LKK: data collection, drafting and finalization of the manuscript; BAK: drafting and correction of the manuscript; DC: correction of the manuscript; JMVB: data collection and entry; MHA: data collection and manuscript correction; AD: data collection; BVJB, MD and EKN: reading and correction of the manuscript.

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