Aedes aegypti and *albopictus* vector control strategies in sub-Saharan Africa : a scoping review

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INTRODUCTION

- *Aedes aegypti* and *Aedes albopictus* mosquitoes are competent vectors for several *Aedes*-transmitted diseases, expanding globally partly driven by the effects of climate change, urbanization, and globalization of travel and trade. The effects of El Niño were substantial in 2023, and a global increase in dengue cases was registered[1]
- Sub-Saharan Africa (SSA) is among the top four regions most affected by arboviral diseases, with outbreaks reported in 15 of 47 countries[1]. There is evidence that dengue is endemic in at least 34 African countries, and modeling suggests that the burden of dengue in SSA is roughly equivalent to that in the Americas without, however, receiving the same attention[2]
- Transmission prevention and effective vector surveillance and vector control (VC) are crucial with integrated VC strategies against the *Aedes* mosquito appearing to be more effective than single interventions. Several examples come from Latin America and Asia, nevertheless conclusive evidence on the effectiveness of such methods available to date is difficult to find in the literature, and little or no data is available from SSA, which instead maintains a rather historic role in *Anopheles* control[3,4,5,6]

Against this background and considering the relevance of contextually adapted VC tools, our review aims to assess the scope of the literature in the field of *Aedes aegypti* and *Aedes albopictus* VC in the sub-Saharan African context and specifically to :
a) describe all the interventions and strategies implemented in the field and to
b) identify and compare the entomological and/or epidemiological outcomes of the selected studies

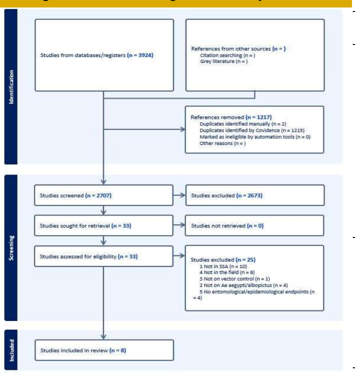
METHODS

- Our scoping review conformed to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews checklist and framed within the SPICE framework. The protocol was published in the Zenodo repository available at https://doi.org/10.5281/zenodo.8010539. Guidance was provided by the team's systematic review methodologist
- Keywords were identified based on (i) the specific mosquito population (i.e. *Aedes aegypti* and *albopictus*, and alternative names), and (ii) the context of the intervention (i.e. SSA) and combined with appropriate Boolean operators
- Studies were selected from the PubMed and ISI Web of Knowledge databases; as a validity check, Google Scholar was consulted for the first 100 records. Studies were exported to Covidence Web software for duplicate evaluation, title/abstract screening, and full-text evaluation by two independent members. A checklist with exclusion criteria was used. This checklist was calibrated based on the first 20 selected papers and redefined. In case of disagreement, the two evaluators discussed with each other first, and if no agreement was reached, a senior academic researcher was consulted
- An evaluation of the initial results of the search criteria was requested from the VC experts to identify possible grey literature. A single reviewer data extraction process was performed with subsequent checking. Relevant data including the type of intervention, entomological and epidemiological outcomes, strengths and limitations of the studies were extracted

RESULTS 1

- From 3924 articles, after removing duplicates, 2707 were screened by title/abstract, of which 34 remained for full-text screening and 8 final papers were included (**Figure1**)
- Four papers were from West Africa (3 from Burkina Faso and 1 from Ivory Coast). The other 4 from Ethiopia, Gabon, Kenya, and Sudan (**Figure2**)
- Non-chemical methods against larvae/pupae were used in most studies (6/8), chemical methods against adult stages in 4 papers, and chemical methods against immature stages in 2 papers. There were no studies evaluating non-chemical methods against adult *Aedes* mosquitoes
- Two studies were conducted during outbreak (Sudan and Ethiopia) and using combinations of chemical and non-chemical VC measures against all stages of the *Aedes* mosquito
- **Table1, Table2** and **Table3** illustrate the main characteristics of the included papers and summarize the most relevant data extracted

Figure1. PRISMA Flow Diagram - *extracted from Covidence*



ID			1	2	3	4	5	6	7	8
Paper	First author, Year		*Gabor, 2016*	*Waldetensai, 2021*	*Ouédraogo, 2018*	*Bonnet, 2020*	*Dambach, 2021*	*Seidahmed, 2012*	*Kone, 2005*	*Forsyth, 2022*
	Country		*Gabon*	*Ethiopia*	*Burkina Faso*	*Burkina Faso*	*Burkina Faso*	*Sudan*	*Ivory Coast*	*Kenya*
Description	Study type	Retrosp. cohort								
		Pre-post study								
		Cluster RCT								
		Case-study								
	Outbreak setting			*CHIKV outbreak*				*DENV outbreak*		
Intervention	Immature Chemical			*Temephos*				*Temephos*		
	Adult - Chemical		*ITNs*	*Propoxur*				*Permethrin LLINs Topical repellents*	*Deltamethrine*	
	Immature Non chemical			*Environ. managem.*	*Environ. managem.*	*Environ. managem.*	*Bti*	*Environ. managem.*		*Environ. managem.*
Community participation										
Outcome	Entomol. indices					*Spatial analysis*				
	Epidemiol. indices		*DENV and CHIKV serology*					*DENV serology molecular*		
	Knowledge									
	Behavior									
Qualitative assessment										

Table1. Main characteristics

RESULTS 2

Table2. Most relevant extracted data (paper 1-4)

	Country, Author, Year	Study design	Intervention(s)	Indicator(s)	Main results
1	Sudan, Seidahmed, 2012[7]	Pre-post study IMPLEMENTATION w10 to w21 EVALUATION Entomol, w9 to w22 Epidemiol, w7 to w31	• Community mobilization • Indoor and outdoor thermal fogging and ULV sprays of Permethrin • Chemical larviciding with Temephos of outdoor containers • Distribution of LLINs • Daytime repellents use	• Entomol (CI, HI, BI, P/PI) • Epidemiol (N of human DENV cases)	• Infested indoor water storage containers 22% • Significant reduction of HI (from 100% to 16%) and P/PI (from 0.77 to 0.10) • The coverage rate of community mobilization was > 70% • By regression analysis, a significant relationship was found between the entomological parameters and dengue incidence over the weeks of surveillance ($R2 = 0.83$, $F = 23.9$, $P < 0.001$)
2	Ethiopia, Waldetensai, 2021[8]	Pre-post study IMPLEMENTATION Aug2019 to Oct2019 EVALUATION Pre-, Aug2019 Post-, w1 after implementation	• Chemical indoor and outdoor space spraying of Propoxur • Chemical larvicides Temephos in stored water • Environ management • Community education	• Entomol (N of adult mosquitoes, HI, CI, BI, PI)	• Outdoor clean water containers the most infested : tire (25.2%) > barrel (17.8%) • After the intervention, *Aedes* adult mosquitoes reduced in all resting sites at the daytime ($P = 0.031$) • Reduction of CI (from 92.9% to 14.7%), BI (from 141% to 20.1%), HI (from 90.1% to 7.4%) and PI (from 1431.4 to 4.12)
3	Burkina Faso, Ouédraogo, 2018[9]	Cluster RCT IMPLEMENTATION Jun2016 to Oct2016 EVALUATION Pre-, Oct2015 Post-, Oct2016	• Community education / environ management *at house level	• Epidemiol (human biomarkers for *Aedes* exposure) • Entomol (CI, HI, BI, PI, N of water breeding sites*, N of containers with larvae/pupae*, N of larvae*, N of pupae*) • KAP	• By regression analysis, the intervention reduced exposure to *Aedes* bites (coefficient –0.08 [95% CI –0.11 to –0.04]) • CI, HI, BI, PI : all reduced in the intervention arm and little or no change or increase in the control arm • By regression model, the intervention did not show an effect on the absolute N of *Aedes aegypti* mosquito breeding sites or on the N of larvae/pupae • In the intervention arm, increase in DENV knowledge (risk ratio [RR] 1.13 [95% CI 1.01–1.27]) and in the self-reported actions against mosquitoes (risk ratio [RR] 1.42 [95% CI 1.29–1.57])
4	Burkina Faso, Bonnet, 2020[10]	Case study based on the previous Cluster RCT (Ouédraogo, 2018)	As illustrated in Ouédraogo, 2018	• Entomol (CI, HI, BI, P/PI, N of larvae and pupae, N of larvae/ inhabitant at the household level)	• CI, HI, BI, PI : as Ouédraogo, 2018 • After the intervention, immature stages were significantly fewer in the intervention arm than in the control ($t = 2.362$; $P = 0.0186$) • Discarded containers were the most infested (68.8% and 62.4% in control and intervention respectively) • The average difference of the proportion of positive containers between the intervention and control arms was 9.67% (95% CI: 1.1–18.3%) • Spatial analysis showed that after the intervention, the N of concentration areas of high and low values of pupae was reduced in the intervention arm

RESULTS 3

Table3. Most relevant extracted data (paper 5-8)

	Country, Author, Year	Study design	Intervention(s)	Indicator(s)	Main results
5	Kenya, Forsyth, 2022[11]	Matched-pair cluster RCT IMPLEMENTATION May2017 to Jul2017 EVALUATION Pre-, at baseline Post-, at mo3, mo12, mo12 to mo15 (qualitative only) Extension intervention to arm control end of 2018	• CBI for source reduction behaviors	• Knowledge • Behaviors (self-reported and observed) • Entomol (CI, HI, N containers /household) • Qual evaluation	• Knowledge increased in the intervention (adj risk difference 0.69, 95% CI [0.56 to 0.82]) • Self-reported behavior improved in the intervention (adj risk difference 0.58, 95% CI [0.43 to 0.73]) • Observed behaviors no significant difference • The type of containers for immature mosquitoes laundry recipients > containers with no purpose • CI and HI showed no difference at mo12 • *'Intention to cover'* was the most frequent Referred barriers: interference from others, losing covers. Facilitators: concerns about hygiene, disease prevention
6	Burkina Faso, Dambach, 2021[12]	Cluster RCT Three study arms i) control ii) Bti 100% iii) Bti 50% IMPLEMENTATION 2014 (data available) 2015 (not available) EVALUATION Pre-, Sep to Dec2013 Post-, Jun to Nov2014	• Bti application every ten days, up to six weeks after the rainy season in public spaces only, followed by a quality control test the day after application	• Entomol (mosquito abundance by indoor and outdoor light traps)	• *Aedes* capture predominantly indoor at 57% ($P = 0.071$) • *Aedes* mosquito abundance significantly reduced by 34% (vs 70% reduction of *Anopheles*) in the full treatment arm (rate ratio RR 0.66, 95% CI: 0.57–0.76) but not in the guided treatment (rate ratio RR 0.94, 95% CI: 0.85–1.05) • Major impact in the semi-urban town > in the rural villages and during August, rise in *Aedes* N in September and October
7	Gabon, Gabor, 2016[13]	Retrospective cohort study Study duration, Dec2002 to Apr2007	• ITNs	• Epidemiol (DENV/CHIKV IgG seroprevalence) • ITNs use • vaccination status (YF)	• Increase in DENV seropositivity (from 1.2% to 12.3%), possible DENV infection in 13 children, in a proportion of cases, interpretation of individual DENV serology results was vague • Stable CHIKV seropositivity (0.6%) • Decrease in the ITNs use (96% to 79%) • No correlation between reported bed net use and DENV/CHIKV seropositivity
8	Ivory Coast, Kone, 2005[14] *in French*	Pre-post study IMPLEMENTATION May1997 EVALUATION Pre-, before the first application Post-, i) after the first application ii) 5d after the second application	• Two ULV applications of deltamethrine one week apart in two different communes (one maritime site and one forest site)	• Entomol (mosquito abundance by indoor and outdoor human capture)	• *Aedes aegypti* abundance reduced in both sites after first application: maritime 37.5% reduction vs forest 66% reduction • Bites/human/evening : 5.58 vs 2.5 maritime vs forest • Endophagic : 69% vs 11% maritime vs forest • *Aedes aegypti* abundance back to the pre-intervention values in both sites, 5 days after the second ULV application

LEGEND Table1, Table2, Table3 : adj adjusted, BI Breteau index, Bti Bacillus thuringiensis israelensis, CBI community-based intervention, CHIKV Chikungunya virus, CI Container index, 95% CI 95% confidence interval, d days, DENV Dengue virus, Entomol entomologic, Environ environmental, Epidemiol epidemiologic, HI House index, IgG immunoglobulin G, ITN insecticide-treated net, KAP knowledge attitude practice, LLIN long lasting insecticidal net, mo month, N number, PI pupae index, P/PI pupal/person index, Qual qualitative, RCT randomized controlled trial, Retrosp retrospective, ULV ultra-low volume, YF yellow fever, w week

DISCUSSION AND CONCLUSIONS

- Eight papers evaluated VC tools against *Aedes* implemented in SSA since 2000, with heterogeneous results in terms of both methods implemented and impact assessment
- Most studies evaluated **environmental management based on community participation**, showing improved knowledge and self-reported behaviors, but not always corresponding to impact in terms of sustained human behavior change and/or entomological indices
- **Chemical interventions against mature and immature stages of *Aedes***, stand-alone or as part of an integrated VC strategy demonstrated the beneficial impact on entomological indices. The use of **epidemiological indicators was scarce**, limiting the estimation of possible benefits on the risk of acquiring *Aedes* infection in the human population
- Epidemiological and entomological surveillance provides a good basis for the evaluation of VC interventions. **Integrating qualitative analysis** would help in understanding human behavior and pathways to behavioral change. VC interventions need to be **optimized and adapted to context** (i.e. mosquitoes bio-ecology, human behaviors, insecticide resistance profiles)
- The epidemiology of *Aedes*-transmitted diseases is expected to change due to climate change, among other factors. Therefore, **integrating climatic factors** into VC strategies has significant implications for planning effective public health vector control programs. VC remains pivotal for the control and mitigation of *Aedes*-transmitted diseases. Hence the need to study the impact of current and new VC tools in SSA.

Figure2. Number of included papers by country

REFERENCES : 1 WHO Dengue global situation 2023, 2 Gainor EM *viruses* 2022, 3 Bowman LR *PLoS Negl Trop Dis* 2016, 4 Bouzid M *PLoS Negl Trop Dis* 2016, 5 Alvarado-Castro V *BMC public health* 2017, 6 Montenegro-Quiñonez CA *Lancet* 2023, 7 Seidahmed OME *EMHJ* 2012, 8 Waldetensai A *Int J Trop Insect Sci* 2021, 9 Ouédraogo S *Emerg Infect Dis* 2018, 10 Bonnet E *Infect Dis Poverty* 2020, 11 Forsyth JE *PLoS Negl Trop Dis* 2022, 12 Dambach P *PLOS One* 2021, 13 Gabor JJ *Travel Med Infect Di 2016*, 14 Kone AB *Dakar méd* 2005

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