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ORIGINAL ARTICLE

Effects of Integrated Vector Management in the Control of Malaria Infection: An Intervention Study in a Malaria Endemic Community in Nigeria

Effets de la Gestion Intégrée des Vecteurs dans le Contrôle de l'Infection par le Paludisme : Une Étude d'Intervention dans une Communauté où le Paludisme est Endémique au Nigeria

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ABSTRACT

BACKGROUND/AIM: Malaria is a vector borne disease with high morbidity and mortality in endemic regions. In view to eliminating the disease, integrated vector and environmental hygiene practices have been advocated. There is paucity of studies on the effect of vector control measures on asymptomatic malaria infection which has been observed to be a reflection of malaria transmission.

METHODS: Longitudinal community-based intervention study carried out from October to December 2017. Study participants were 477 individuals living in 100 households selected by snow-balling sampling methods. Pre-intervention period included training of all heads of households on vector control methods. During the intervention period, each household received waste bins, two long lasting insecticide bed nets and had wire screen on their doors and windows; every household member was screened for malaria (antigen) using the pf rapid diagnostic test kits. Each household were monitored to ensure they comply with the environmental hygiene practices they were taught. Post-intervention malaria infection was obtained at 8 week being end of the intervention period.

RESULTS: Of the 100 households selected, 54.0% were from the lower social class, 45.0% middle class and only 1.0% upper class. Mean age [±] of the heads of the households was 37.1 ± 11.0 (range 16–68) years. There were 477 individuals recruited in the study from the 100 households; 234 (49.0%) females and 243 (51.0%) males; median age was 20.0 (range 1–100) years. Prevalence of malaria infection using mRDT during pre-intervention was 16.8% and an incidence of 1.3% post-intervention. There was 92.0% reduction in asymptomatic malaria infection showing marked reduction in malaria transmission in the study locale.

CONCLUSION: Some integrated vector control measures such as use of insecticide-treated net and sanitation were found effective methods for reducing malaria infection and transmission in endemic region. **WAJM 2023; 40(1): 45–54.**

Keywords: Endemic, Environmental hygiene, Households, Intervention, Malaria, Transmission, Vector.

RÉSUMÉ

CONTEXTE/OBJECTIF: Le paludisme est une maladie à transmission vectorielle avec une morbidité et une mortalité élevées dans les régions endémiques. En vue d'éliminer la maladie, des pratiques d'hygiène intégrée des vecteurs et de l'environnement ont été préconisées. Il existe peu d'études sur l'effet des mesures de lutte antivectorielle sur l'infection palustre asymptomatique, qui s'est avérée être le reflet de la transmission du paludisme.

MÉTHODES: Étude longitudinale d'intervention communautaire réalisée d'octobre à décembre 2017. Les participants à l'étude étaient 477 personnes vivant dans 100 ménages sélectionnés par des méthodes d'échantillonnage en boule de neige. La période de pré-intervention comprenait la formation de tous les chefs de ménage sur les méthodes de lutte antivectorielle. Au cours de la période d'intervention, chaque ménage a reçu des poubelles, deux moustiquaires à insecticide longue durée et avait des grillages sur leurs portes et fenêtres ; chaque membre du ménage a été dépisté pour le paludisme (antigène) à l'aide des kits de test de diagnostic rapide pf. Chaque ménage a été suivi pour s'assurer qu'il respecte les pratiques d'hygiène environnementale qui lui ont été enseignées. L'infection antipaludique post-intervention a été obtenue à 8 semaines, fin de la période d'intervention.

RÉSULTATS: Sur les 100 ménages sélectionnés, 54,0% appartenaient à la classe sociale inférieure, 45,0% à la classe moyenne et seulement 1,0% à la classe supérieure. L'âge moyen [±] des chefs de ménage était de 37,1 ± 11,0 (fourchette de 16 à 68) ans. Il y avait 477 personnes recrutées dans l'étude à partir des 100 ménages ; 234 (49,0 %) femmes et 243 (51,0 %) hommes ; l'âge médian était de 20,0 (intervalle de 1 à 100) ans. La prévalence de l'infection du paludisme à l'aide de mRDT pendant la pré-intervention était de 16,8 % et l'incidence de 1,3 % après l'intervention. Il y avait une réduction de 92,0 % de l'infection asymptomatique du paludisme, montrant une réduction marquée de la transmission du paludisme dans le lieu de l'étude.

CONCLUSION: Certaines mesures intégrées de lutte antivectorielle telles que l'utilisation de moustiquaires imprégnées d'insecticide et l'assainissement se sont révélées être des méthodes efficaces pour réduire l'infection et la transmission du paludisme dans les régions endémiques. **WAJM 2023; 40(1): 45–54.**

Mots clés: Endémique, Hygiène Environnementale, Ménages, Intervention, Paludisme, Transmission, Vecteur.

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INTRODUCTION

Malaria is a parasitic disease responsible for nearly 500,000 deaths annually worldwide.[1] Nineteen countries in sub-Saharan Africa and India are responsible for 85.0% of the global malaria burden with Nigeria contributing 25.0% of total malaria cases and deaths globally. Nearly 97.0% of the approximately 200 million Nigerians are at risk of malaria.[1] Malaria is transmitted mainly through the bite of an infected female anopheline mosquito. The intensity of malaria transmission depends on prevalence of malaria parasite/vector, immunity of the human host and the characteristics of the environment.[2] Level of malaria parasitaemia (active and asymptomatic) is an indicator of intensity of malaria transmission.[2–6] Attempts at malaria control have largely focused on symptomatic malaria through prompt diagnosis and treatment.[7] with less emphasis on asymptomatic cases. Meanwhile, the latter is known to contribute more to reservoir of malaria transmission.[3–6]

Asymptomatic malaria parasitaemia (ASMP) is the presence of malaria parasitaemia without features compatible with the clinical disease in an individual who had been followed up for a minimum of four week.[4–6] The national average crude ASMP rate varies from one location to another and ranges between 20.0% in holoendemic areas to 80.0% in hyperendemic regions.[6] Locale specific prevalence of ASMP include 74.0% in 1990 in South-western Nigeria [9]22.5% in 2002 in North-west Nigeria;[10] and 68.4%[11]in 2002 in Benin, South-south Nigeria by Woghiren. Fifteen years after Woghiren study in Benin City, Ifebi *et al* observed a lower prevalence of 29.9% in Benin, South-south Nigeria.[12] Malaria parasitaemia is established by microscopy, the gold standard for malaria diagnosis. Microscopy, however, is constrained by non-availability of skilled personnel, poor energy supply and lack of equipment.

These limitations are the hallmark of resource poor countries such as Nigeria. In an apparent bid to circumvent these constraints, the World Health Organisation (WHO) recommends antigen-based mRDT as a cost effective, efficient and easy method for malaria diagnosis. The sensitivity and specificity of mRDT surpasses 95%;[13–14] warranting its use and acceptability in the diagnosis of uncomplicated malaria in all age groups at the Primary Health Care (PHC) level and other peripheral health facilities. Although, mRDT is qualitative and unable to quantify parasitaemia, its rate of positivity in epidemiological surveys has given credence to the fact that it is at least as sensitive as microscopy in the demonstration of the parasite or its surrogate, the antigen. In the Nigerian 2015 National Malaria Indicator Survey (NMIS) the overall national malaria antigenaemia prevalence was 45.1% as against concomitant malaria parasitaemia prevalence of 27.4%[15] perhaps suggesting that asymptomatic malaria antigenaemia rate (AMAR) may have an edge over malaria parasitaemia rate as a reflection of malaria transmission in a community.[15]

Prior to the Roll Back Malaria (RBM) initiative, malaria vector control was essentially mono-pronged, entailing use of insecticide sprays, screens/ gauze on doors/windows, mosquito nets (non-insecticide-treated), clearing of gutters, and fumigation. These methods were used in isolation of one another and were found to be ineffective as malaria burden and transmission increased exponentially warranting the introduction of the Integrated Vector Management (IVM) in the RBM strategy in 1998.[16–18]

IVM is a composite and holistic approach to malaria vector control and when effectively carried out it can reduce malaria transmission.[2,7,18] IVM is aimed at improving efficacy, cost-effectiveness, ecological soundness and sustainability of malaria vector control. It encourages a multi-prong approach rather than relying on isolated methods of vector control. In principle, IVM consists of environmental modification (flushing and clearing reservoirs that can help reduce the availability of vector habitats); environmental manipulation (elimination of breeding sites of mosquitoes); human settlement siting and management; use of natural predators for larvae control and use of non-biologic larvicides/ adulticides/long lasting insecticide-treated nets (LLIN) with the ultimate goal of reducing malaria transmission (active and asymptomatic infections).[2,18] In recent times, emphasis on malaria vector control across the country shifted to distribution, ownership and use of LLIN and indoor residual sprays (IRS). LLIN and IRS, are the most cost effective methods of vector control,[18] and have been observed to reduce malaria parasite transmission by $\geq$ 90%.[18,19] However, both methods involve killing or reducing the lifespan of female mosquitoes using pyrethroids. There are emerging reports of evolution and spread of resistance to pyrethroids which may in the long run render these vector control methods ineffective especially as they are used in isolation of each other.[20] Undue emphasis on these two vector control methods to the exclusion of other components of IVM could mitigate the gains of the malaria control programme. Some of the red flags in this conjecture have been highlighted by Nwaneri *et al* in their hospital-based study which showed that combined vector control measures as against the sole use of LLIN significantly predicted low prevalence of severe malaria.[17] Other studies have documented similar findings but most are hamstrung by the fact that they were institution-based, utilised parasitaemia rather than antigenaemia (which may have under-estimated the real effect of IVM on malaria transmission) and documented point-prevalence.[17,21–22] There is, therefore, the need for a longitudinal, community-based intervention study to evaluate the effects of IVM interventions on malaria transmission using asymptomatic malaria infection as an indicator.

Study Hypothesis

Null Hypothesis: Effective environmental management and comprehensive vector control practices have no significant effect on asymptomatic malaria infection among adults and children in a longitudinal community-based intervention study.

Alternate Hypothesis: Effective environmental management and comprehensive vector control practices have significant effect on asymptomatic malaria infection among adults and children in a longitudinal community-based intervention study.

Research Questions

1. What is the asymptomatic malaria infection rate of both adults and children in a selected community using mRDT?
2. Does an effective environmental management and some vector control methods able to significantly reduce the levels of malaria infection in adults and children in a longitudinal community-based study?

STUDY PARTICIPANTS AND METHODS

The community-based descriptive and longitudinal study was carried out between June and December 2017; as part of a malaria control project implemented by Development Africa (DA) Lagos, under the Development Africa Malaria Elimination Programme (DAMEP) Initiative. DA is a non-governmental organization working to provide immediate reliefs and sustainable solutions through healthcare interventions, training, and education in order to alleviate the poverty and sufferings of vulnerable groups in Nigeria. DA has been working in partnership with the National Malaria Elimination Programme (NMEP) at the federal level and has been involved in various malaria elimination programmes in several States in Nigeria in the past 10 years preceding this study.

This index intervention programme combined techniques of environmental sanitation/management, proven preventive and therapeutic interventions (use of LLINs) and information, education and communication (IEC) deployment (in the training of study participants) as intervention tools in malaria control. The programme aimed at treating/preventing malaria infection and changing the behavioral patterns and social systems of the inhabitants of the community themselves. While the programme was being conceptualized, a research component was built in and designed to evaluate the impact of the programme on incidence of malaria infection in the beneficiary community.

The study established a public health alliance, including both a therapeutic and preventive union, with individuals, healthcare workers and members of the community to promote not only the treatment and prevention of malaria, but the reduction of mosquito breeding sites. The environmental modification and manipulation techniques and in-depth training for community agents and healthcare workers on environmental sanitation practices regulated the micro-environmental conditions and were expected to provide long-term intervention reliefs against malaria transmission.

The entire programme including the research component was carried out in Igboghene community in Yenagoa, Bayelsa State, Nigeria. Bayelsa State is located within the swampy riverine terrain of the Niger-Delta where malaria transmission is holo-endemic and stable throughout the year.[7,15] The vegetation of the State is mainly Mangrove forest interspersed by pockets of Tropical Rain forest which support the breeding of malaria vector (anopheles mosquito) especially *Anopheles gambiese* and *Anopheles arabiensis*.[15,16] The weather condition of the study locale (mean annual temperature of 28.7 ^{o}C; humidity >88% and mean annual rainfall in excess of 2200 mm) favor the breeding of the vectors. These features coupled with poor environmental sanitation and widespread poverty as found in the locale, enhance mosquito breeding, promote their survival, as well as proliferation of the malaria vector and parasites. [7,15]

Igboghene is a semi-urban community at the fringes of the Cosmopolitan City of Yenegoa, the Capital of Bayelsa State. Malaria infection in the State according to the 2015 National Malaria Indicator Survey was 36.1% (the highest value obtained and only second to Cross River State in the South-south region of Nigeria; Figure 1).[15] The entrance to the community is a long straight road which is a detour off the popular East-West Road; bounded by Mbiama/Port Harcourt on the East and Patani/Mbiama on the West; Owerri in the North and tributaries of the Atlantic ocean in the South.

The inhabitants are civil servants, fishermen/women, traders, artisans, and farmers. The community is a typical African setting and consists of semi-modern houses arranged as a linear settlement. Each house on the street is owned by a particular family and it is made up of one and/or maximum of two households and the environment is characterized by features that enhance the breeding of mosquitoes.

The study was carried out in 3 phases as outlined – Pre-Intervention, Intervention and Post-Intervention phases.

(I) Pre-intervention Phase

This involved pre-intervention procedures: – identification and involvement of key opinion leaders/ stakeholders in the State, Local Government Area, Ministries of Health as well as key opinion leaders (KOL)/ community influencers: The scopes of the project, timeline, and expected outputs were properly outlined at every inter-phase with these key stakeholders as highlighted in Schema 1. The duration was five months.

Selection of Households and Study Participants.

The physical count showed that there were a 1000 households in the community but for purposive and convenience of sampling, one hundred households were selected for the study considering the available resources needed to implement effective vector control and environmental hygiene practices/ management. The selected 100 households formed a cohort for which all aspects and scopes of the operational/ intervention processes of the study were administered as outlined in Schema 2.

The first house on the street in the community was selected as the starting point. Subsequent houses were selected in a snow-balling format from both sides of the street until 100 households were enrolled. Every member living in each household selected was enrolled in the study.

(II) Intervention Phase

The intervention phase lasted 3 months. Highlights of activities in this phase were: a focused capacity development exercise for health workers and medical personnel working in the community with emphases on current malaria prevention and treatment

methods using the National Malaria Elimination Programme's (NMEP) training manual. Members of the community and especially heads of selected households were trained on vector control measures and environmental hygiene practices. They were educated on how to use the interventional materials and how to deploy environmental sanitation methods for malaria control/elimination. These included vegetation and waste control, removal of stagnant water and clearing of drainage. During the period, research assistants spearheaded clearing of bushes around houses in the community, removal of garbage heaps, and ensuring their deposition in government allocated dump sites. At this phase, two waste bins (one each for organic and one for recyclable/ other wastes) were distributed to each selected household in the community.

Two community compost bins built in designated sites in the community were formally commissioned. The compost bins were parts of efforts to promote recycling and composting of waste. Other activities in this phase included free malaria screening and treatment for every member in each selected household as well as each household receiving two LLINs. Other households in the selected communities also benefited from LLIN by receiving two per household.

This also entailed the evaluation of the key performance indicator: determination of malaria infection rate using mRDT at the beginning of the intervention, hereafter designated 'pre-intervention malaria infection rate (MIR),' performed using mRDT kits in accordance with manufacturer's recommendations the post-intervention MIR.

The deliverable during the intervention phase were carried out as follows:

(a) ***Community awareness*** – This highlighted the scope of the project and expected deliverable and was achieved through a well-organized sensitization programme at the community. IEC and behavioral change materials on vector control practices in the community and hygiene practices were made available to community members.

Schema I: Scope of Work and Timeline of Execution/Outputs

- Meeting with stakeholders – State and Local Government Ministries of Health and key Opinion Leaders/ Community Influencers (month one)
- Environmental sanitation and management (month two to five)
- Survey of target communities and formulation of tailored action plan
- Appointment of environmental sanitation officers, community volunteers and agents
- Removal of stagnant water and drainage clearing
- Vegetation control; removal of bushes surrounding the houses
- Waste control: removal of garbage heaps to government allocated dumps
- Procurement/ supply of waste bins for households: two bins per household (for organic waste and recyclable waste)
- Building of community compost bins away from houses
- Promotion of recycling initiatives for waste management
- Identification of recycling businesses already installed in the community for possible collection route of accumulated recyclable items (free contribution or potential purchase)
- Encouragement of daily/weekly waste and drainage clearing, removal of stagnant water, etc., by representatives from each household (likely a female member of the household)
- Preparation for the community intervention and it involved mRDT testing and treatment pre/post project; LLIN distribution to members of families in each selected households; and installation of LLINs in the households.

Schema II: Commodities deliverable to the Selected Households and Study Participants

No.	Commodity Deliverables	Quantity
1.	Number of households benefiting from the project	100
2.	Organic waste and recyclable waste bins distributed – two per household	200
3.	Compost units built and functioning	2
4.	LLINs (bed net) distribution	3,500
5.	Malaria test kits (RDT's) and consumables	1,000
6.	Malaria medicine (ACT) & IPT	900
7.	One-day in-depth interactive training for health workers and community members in Environmental Sanitation for Malaria Elinication. Target Recipients: Community health workers, nurses, doctors, community volunteers, household representatives.	70
8.	Two-day training of health workers and medical personnel in current malaria prevention practices and RDT usage using the FMoH/NMEP national training manual on malaria diagnosis and control (including training manuals, branded polo shirts, certificates, lunch, refreshments and transport).	40
9.	Training for host community secondary school students and teachers in environmental sanitation, malaria prevention, elimincation and awareness.	200
10.	Printing and distribution of Trifold educational fliers in the communities.	5,000

(b) ***Training processes are highlighted in Schema 3 and 4.***

(c) ***Provision of intervention materials and commodities to each selected household.***

This entailed provision and distribution of vector control and environmental hygiene materials (waste bins, netting of household doors/ windows and LLINs (minimum of two per households).

(d) ***Intervention proper***

Data were collected using a researcher-administered semi-

Schema III: Training of Heads of Households on Environmental Management and Hygiene Practices

Date of Training:	**October 2017**
Venue:	**Community Town Hall**
Major Activity	**One Day training on Environmental Management**
Sub-Activities	Power point Presentations
	Facilitations
Expected output	Sanitation Training Focus
	Behavioral changes
	Waste control
	Hygiene practices
	Sustainability
Methodology	Participants were Doctors, Pharmacists, Nurses and Community Health Officers, Environmental Health Officers and community agents; a total of seventy (70) participants.
	Two trainers both of which were authors in this intervention and operational research. Adult education approach was applied in the facilitation
Topics discussed	Introduction – overview of malaria parasite-human and mosquito host relationship and the environment
	Disruption of Vectors' Breeding Grounds
	Integrated vector management
	Vegetation Control and Environmental Manipulation, Sanitation and Drainage
	Waste Refuse and Recycling; Organic Composting for Farming Conclusion.

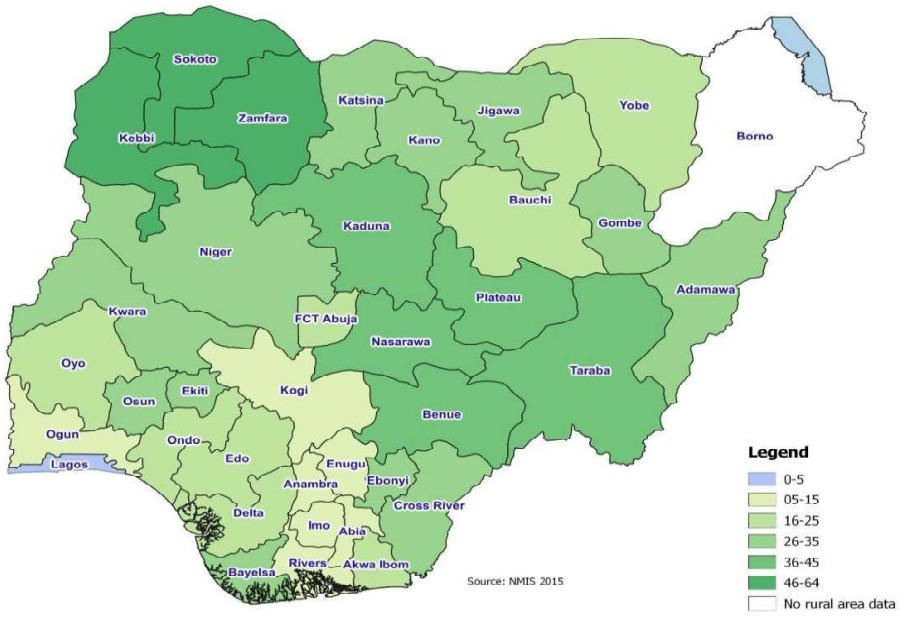

Fig. 1: ***Source:*** **Nigerian Malaria Indicator Survey 2017.**
Courtesy of Malaria Consortium, Nigeria.

structured questionnaire. The tool was validated by extensive literature review and was pre-tested on 20 persons selected from households in a nearby community who were not part of the study. The questionnaire sought the following information: demographic features of the selected participants, knowledge/attitudes, and malaria vector control practices. The social class of participants were determined as described by Olusanya *et al*,[23] Households were categorized as small if they contained d" 5 individuals and large if they contained >5 individuals.[24]

Malaria antigenaemic test was done on each study participant at recruitment (day zero) and at the 28th day using the pfRDT Standard Diagnostic (SD) Bioline Malaria Antigen pf test (Kyonggi-do, Korea). (Internal evaluation of the pfRDT SD Bioline kits as certified by WHO showed that the kit has 100.0% sensitivity for parasite count in excess of 50 parasite/µL and 98.0% specificity for *P. falciparum)*. The kits had storage temperature range of one to 40°C which was within the average environmental temperature in the community.

Persons who were antigenaemia positive were treated with artemisinine-based combination therapy (ACT) according to the National Guideline. All individuals with fever at the time of recruitment were tested and if positive for malaria were also treated with the recommended ACT, but, were all excluded from the study. Also excluded from the study were persons who had access to anti-malarial one-month preceding enrolment.

(e) ***Monitoring/Evaluation***

There was weekly monitoring of each household throughout this phase to ensure compliance with use of environmental management instructions and observance of the necessary environmental hygiene etiquette. For example, emphases were laid on reuse of plastic

Schema IV: Training of Health Workers on Current Community Case Management of Malaria

Date of Training:	**3 Days Training, October 2017**
Venue:	**Community Town Hall**
Targets	Healthcare providers namely Doctors, Nurses, Pharmacists, Laboratory Scientists, Environmental Health Officer, Community Health Officers from selected Primary & secondary Health Facilities and State Ministry of Health in Yenegoa, Bayelsa State. Total number of participants was forty-one (41)
Major Activity	A 3-Day training Malaria case Management at the Community with emphasis on Management of Uncomplicated and Severe malaria including the role of Rapid Diagnostic Tests (RDT) in Diagnosis. Other component of the training included Indication for Referral of Severe Malaria Cases, Malaria in Pregnancy & Congenital/ Neonatal Malaria, Phenomenon of Home-based management of Malaria, Integrated Vector Management and Routine Surveillance in malaria case management.
Sub-Activities	Power point Presentations Group Works/ Hands-on Practical Sessions Facilitations Exercises
Specific Objective (SO)	Build capacity of the Healthcare workers at the Primary Health Care Level in the management of uncomplicated and severe malaria in line with the current national guideline.
Methodology	Participants (Doctors, Pharmacists, Nurses and Community Health Officers) selected from facilities in the LGA. The training session was facilitated by one of two of the authors using the adult education approach. There were two assistants who handled the logistic aspect such as provision of training materials, setting up, administration of pre-and-post evaluation tests.
Output	The 3-day Training Session was completed
Output Indicators	Training on malaria case management completedCapacity of the health workers across from the selected LGA was built
Outcome	Participants would be able to practice all the information as delivered from the national Malaria Guideline / Module for Malaria Case Management at the Primary Health Care level. Best practices by participants in the management of uncomplicated and severe malaria.
Outcome Indicators	Health workers capacity was built on antimalarial drug policy. It is envisaged that the health workers shall continually practice what they were taught according to the protocols contained in the Module 2 / Guideline for Management of Uncomplicated and Severe Malaria.

materials and recycling of these materials where applicable. Appropriate dumping sites were provided in the community and inhabitants were taught ideal disposable practice measures while the relevant government agency regularly evacuated the rubbish to government designated dumping sites. Bushes around houses were cut as at when due and clearing of water drainage and stagnant water bodies in the community were routinely done throughout the period.

Household members were encouraged to sleep under LLIN given to them. The health care centres in the community were provided with mRDT kits and the recommended anti-malaria drugs (ACTs) for treatment of individuals with malaria in the community irrespective of whether or not they were recruited into the study. Study participants who developed fever during the course of the study were noted and were taken to the health centre for malaria diagnosis and treatment where applicable. Such confirmed cases were regarded as positive during the post-intervention phase.

(III) Post-intervention Phase

The post-intervention phased lasted two months (8 weeks) and comprised the following deliverable:

- Re-screening for malaria for every household member enrolled in the study using the same pfRDT kits at the 28th day after the first sampling at recruitment.
- Composting of materials at the dump sites in the community
- Evaluation, analysis of data and Report writing

The most important key performance indicators (KPIs) measured were the MIRs pre-and-post-intervention.

Ethical Considerations

Ethical clearance was obtained from the Research and Ethics Committee of College of Medical Sciences, University of Benin and the Bayelsa State Ministry of Health Research Statistics. Written informed consents were obtained from heads of household and verbal consent/ assent (where applicable), from study participants.

Data Analysis

The data obtained were analyzed using the Statistical Package for Social Sciences (SPSS) version 16.0 (Chicago, Illinois, USA). Further analysis was by

Schema V: Performance Metrics

Direct Beneficiary	Target	Actual	Outcome- Qualitative Information
Target households	100	100	At Igbogene community.
Health workers trained	40	44	110% – More health workers showed up for the training
Sanitation officers trained	70	74	These play key roles in the intervention phase
LLIN distributed	500	3500	700% – 3000 more LLIN were distributed to reach a broader demography of indirect beneficiary households
LLIN installed	100	200	200% – 200 LLIN were installed in 100 beneficiary households for the purpose of the closed study population
Waste bins distributed	200	205	5 big stationary community waste bins were placed in strategic places around the community
Monitoring/ Evaluation Phase			
Households using LLIN	100	94	Majority of the households were observed to be using the LLIN.
Households not using LLIN regularly	100	89	Households not using LLIN regularly attributed that to hot weather
Households Gutter clearing compliance	100	87	
Household Bush clearing compliance	100	91	
Households using organic waste bins provided	100	91	
Households using recycling waste bins provided	100	94	
Households removing stagnant waters around them	100	92	

the GraphPad InStat Software (GraphPad Software Inc, San Digeo 92130, USA), where applicable.

The outcome variables of interest were prevalence of asymptomatic malaria infection pre-intervention phase and the incidence (new cases) post-intervention phases using mRDT respectively. The pre-and post-intervention asymptomatic malaria infection values were compared and statistical associations with socio-demographic characteristics of the study participants were tested using Chi Square Tests or Fisher's Exact Test where applicable. The binary logistic regression model predicting pre-intervention MIR and post-intervention MIR in the study population was done using the pre-intervention MIR and post-intervention MIR as dependent variables and factors such as age, gender, social class, size of households and age lower than five years as independent. The level of significance of each test was set at $p < 0.05$.

RESULTS

Of the 100 households selected, 54.0% were from the low social class; 45.0%, middle class and 1.0%, upper class. Mean age [±SD] of heads of households was 37.1 ± 11.0 years (range 16 – 68 years). Of these, 22 (22.0%) were females and 78 (78.0%), males. Ninety-five percent were married while 5.0% were single. Thirty-five percent were from large households and 65.0% from small households. Whereas 59 households had at least one under-5; 41 households did not have any child under the age of 5 years. From the 100 households, 477 subjects were recruited into the study; 243 (51.0%) males and 234 (49.0%) females; median age was 20.0 years (range 1 – 100 years). Fifty percent of the study participants were children with mean age [±SD] of 7.7 ± 4.8 years. Complete data were available for 473 persons. Age distribution and mean ages [±SD] of the study participants were as follows: 91 (19.1%) were under-5s [±SD] (2.8 ± 1.5 years); 151 (31.7%) were aged, 6 – 17 years; mean [±SD] (10.8 ± 3.5) years; and 231 (48.4%) were aged ≥18 years; mean [±SD] (34.5 ± 11.8) years.

Prevalence of asymptomatic malaria infection pre-intervention phase was 80/ 477 (16.8%) as against the incidence of

Table 1: Socio-demographic Characteristics of 477 Participants in Relation to Prevalence of Pre-Intervention Malaria Infections using mRDT

Socio-demographic Characteristics	Malaria infections		χ^2	C.I	*p*-value
	Positive (%)	Negative (%)			
Age (years)					
< 5 (n = 92)	8 (8.8)	86 (91.2)	6.99	0.01, 0.04	0.03
6 – 17 (n = 149)	33 (21.9)	118 (78.1)			
≥18 (n = 236)	39 (16.4)	193 (83.6)‘			
Gender					
Male (n = 234)	44 (18.8)	190 (81.2)	1.36	*[a]	0.24
Female (n = 243)	36 (14.8)	207 (85.2)			
Family Social Class					
Upper (n= 12)	2 (16.7)	10 (83.3)	1.59	0.31, 0.5	0.46
Middle (n = 227)	33 (19.0)	194 (81.0)			
Lower (n = 238)	45 (19.0)	193 (81.0)‘			
Household Size					
Small (n = 149)	32 (21.5)	117 (78.5)	3.44	*[b]	0.06
Large (n = 328)	48 (14.6)	280 (85.4)			
Under-5 in the Household					
Yes (n = 92)	8 (8.7)	84 (91.3)	5.33	*[c]	0.03
No (n = 385)	72 (18.7)	313 (81.3)			

**Odds Ratio = 1.3[a] *Odds Ratio = 1.6[b] *Odds Ratio = 0.4[c]*

6/477 (1.3%) post-intervention. There was approximately 92.0% reduction in asymptomatic malaria infection rate following community-based vector control practices.

Table 1 shows the socio-demographic characteristics of the 477 participants in relation to asymptomatic malaria infection rate during the pre-intervention phase. Asymptomatic malaria infection was significantly observed in children aged 6–17 years ($c^2 = 6.99$; 95%C.I = 0.01, 0.04, p = 0.03). The six study participants with asymptomatic malaria infection during the post-intervention phase were aged 6–17 years, all males and were drawn from low socioeconomic class families.

Table 2: Showed the Logistic Regression Model Predicting Pre-Intervention Malaria Infection Rate (MIR) and Post-Intervention MIR in the Study Population

	Pre-intervention MIR			Post-intervention MIR		
Socio-demography	**β**	**O.R.**	***p*-value**	**β**	**O.R.**	***p*-value**
Gender	0.37	1.5	0.14	17.38	0.0	0.99
Age	–0.02	1.0	0.11	–0.12	0.9	0.09
Social Family Class	0.22	1.2	0.35	17.52	0.0	0.99
Household Size	–0.60	0.6	0.03	16.85	0.0	1.0
U-5s in Household	–1.26	0.3	0.00	–18.63	0.0	1.0
Constant	–1.46	0.2	0.04	–87.01	0.00	0.99

β, Measure of how strongly each predictor variable influences the dependent variables; O.R, Odds Ratio, p-value.

DISCUSSION

The study showed a remarkable reduction in asymptomatic malaria infection rate following IVM intervention program in the study locale. This observation is an affirmation of the alternate hypothesis that effective community-based environmental management and vector control practices reduced the incidence of asymptomatic malaria infection (as measured by antigenaemia using mRDT) in a selected population consisting of adults and children. This finding confirms the superiority of multi-prong vector control programme over the mono-prong approaches.[17,18,21,22] In the past (a decade preceding this index study) the prevalent methods of malaria vector control were essentially netting of doors and windows and use of indoor insecticide sprays.[17] Recent progress made in malaria vector control is attributed to use of LLINs and indoor residual spray (IRS) which are two methods that depend on a common pathway – the ability of insecticides to reduce the lifespan of female mosquitoes or kill them entirely.[18–20] These have played major roles in reducing malaria mortality and morbidity in malaria-endemic regions.[17,22,25] Despite these successes, there are reports of emerging resistance to major classes of insecticides recommended for public health across many malaria vector populations.[20,26] Increasingly, malaria vectors are also showing changes in vector behaviour in response to current indoor chemical vector control interventions.[26] Dynamics in mosquito behaviour, such as changes in the time of biting and proportion of indoor biting of major vectors have proposed to threaten the progress made thus far to control malaria transmission.[21,26] Nevertheless, the outcome of this study is a confirmation of the importance of IVM in reducing malaria transmission which is in conformity with the observations of other authors who noted that combined malaria vector control as against use of isolated or single prong method significantly lowered the incidence of malaria infections [17,21,22] The significant reduction in asymptomatic

Schema VI: Illustration Photo – A typical Example of the Community Layout

malaria infection rate in both adults and children as demonstrated in this study has also affirm the prospects for malaria control through a well-articulated IVM at the community level.

The current asymptomatic malaria infection rate of 16.8% pre-intervention is far lower than the 36.2% recorded in Bayelsa State, Nigerian in 2015. This is perhaps due to an existing community-based (albeit not concerted) control programmes predating the intervention. This assertion was buttressed by the post-intervention malaria infection rate of 1.3% following some of the IVM programme instituted within the community (such as use of LLIN, cleaning of gutters, clearing bushes around houses and appropriate garbage and refuse disposal) which could to a large extent reduced the malaria vector reservoirs and breeding sites with the attendant reduction in malaria transmissions. In addition to this, all individuals who were positive for malaria parasites during the pre-intervention phase were treated with the artemisinine-based combination therapy (first line anti-malarial drug known to have good clearance of plasmodium gametocytes) thereby reducing these specialised sexual precursor cells of the plasmodium that mediate transmission of the malaria parasite from human host to the mosquitoes.[27] Reduction in gametocyte has been termed a malaria transmission-blocking intervention as this strategy prevents spread of malaria disease.[17,27] Ifebi *et al*[12] in 2017 observed that there is a shift in malaria transmission from holoendemic to mesoendemic in Egor Local Government Area of Edo State, in the same South-south region; a feat linked to the concerted implementation of effective malaria control programme in that study locale. It could, therefore, be postulated that pre-existing malaria vector control methods reduced malaria transmission to some limited degree. This finding is in tandem with what had been noted by some researchers earlier in Nigeria.[10]

Asymptomatic malaria infection was observed more in children than in adults at the pre-and-post-intervention phases. This is in keeping with findings by other authors who also observed that the odd of having asymptomatic malaria infection was higher in children than in adults suggesting that age is an important risk factor for presence of sub-clinical infections.[3–6] This assertion also underscores the role of sub-optimal immunity in the pathogenesis of malaria.[5,28] Another important finding of this study is the paradigm shift in peak age incidence for malaria infection from under-5s to children above five years of age at both the pre-and-post-intervention phases. Observation of higher malaria infection rates in children older than 5 years is in keeping with recent studies conducted in locations with effective malaria vector control.[12] The reason for this paradigm shift is not fully understood; however, the development of clinical and parasitologic immunity to malaria, marked by individuals' ability to control the disease and parasite density could offer some explanations.[28] Although, some studies have analysed immune responses to malaria as a possible cause, it has not been possible to identify with certainty those that predict naturally acquired immunity nor deûne the *P. falciparum* antigen targets. *P. falciparum*, in particular being such a complex parasite with multiple and changing epitopes could elicit multiple effector feedback that are modulated by host responses. Some epidemiological factors also have been postulated to support this paradigm shift and these include the transmission dynamics of the parasite as orchestrated by possibly environmental factors, the Anopheles mosquito dynamics or behavior factor (time and pattern of flights and bite respectively); and weather (humidity, rainfall, temperature). Whereas environmental factors (flushing and clearing reservoirs meant to reduce vector habitats and eliminate breeding sites of mosquitoes) were well implemented in this study, weather conditions and mosquito dynamics could not be controlled. Nevertheless, the classical epidemiological age pattern described for perennial transmission under normal geographical conditions as implemented in this study showed that younger children bear the brunt of the disease[29] but tend to switch to older children as intensity of transmission decreases as naturally acquired immunity takes longer time to develop thereby exposing older children to higher risk of malaria infections.[28]

CONCLUSION AND RECOMMENDATION

Vector control measures are effective methods in the reduction of malaria transmission. A paradigm shift in malaria epidemiology following effective malaria vector management in a community could occur, causing older children rather than under-fives to have higher incidence of malaria infection. The intervention study confirmed the supremacy of some IVM (such as use of insecticide treated nets and environmental sanitation) over mono prong programmes in the control of malaria in the community. The authors, therefore, recommend scaling-up of IVM in most communities as a veritable tool for malaria control and elimination.

Limitations of Study

In the design of the study, the assumption was that Igboghene is a stable community with little or no human migration. In the interval between pre-and-post interventions some persons may have immigrated to or emigrated from the community. If such did occur, they could have influenced, albeit in a negligible way, the post-intervention malaria infection rate.

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Declaration of Conflicting Interest

None to declare.

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