

A Trial Test of 5AIGRNG Micro-Encapsulated Paint: A Time-Mortality on Aedes Mosquitoes in Selected Communities of Nasarawa State, Nigeria

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Abstract- A trial test of 5AIGRNG micro-encapsulated insecticide paint on Aedes mosquitoes in selected communities of Nasarawa State, Nigeria was determined. Aedes, capable of transmitting deadly infection and afflicted population, posing one of the greatest threats in the history of humanity, and a serious public health concern. Major outbreaks of dengue, yellow fever is rising at alarming rate in Nigeria. WHO cone bio-assay as a testing protocol for bio-efficacy assay with mosquitoes was used for a time-mortality on Aedes mosquitoes. The wall cone bio-assay were mounted at variance, the painted plaster wall was measured at 0.5m, 1.0m, 1.5m height and from the rain water puddles at 30 minutes, Ae aegypti showed resistance in cone 1 and 2 mean percentage variance (70%resistance and 80%resistance), but 98% susceptible susceptibility was observed in cone 3 and at 24hrs post exposure, 100% susceptible susceptibility was met. From West lands, tree holes, water storage containers, and tires, were equally resistance in cone 1, 2, and 3. And at 30m, septic tanks, gutters and drains were 100% susceptible susceptible at 1hr and 24hrs respectively. For Ae albopictus at 30m, 70%resistance knockdown was recorded and 80%resistance at 1hr interval, and a knockdown-make up to 100% susceptible at 24hrs post-exposure of the emulsified insecticide micro-encapsulated product across all sites of larval collection. Rainwater puddles, and west lands at 0.5m height were resistance while from the tree holes 98% susceptible was susceptible at 1hr, water storage containers, tires, septic tanks, gutters and drains were in any case resistance in all the three trial test of the cone bio-assay at 30m, and 1hr respectively. This new product should fast be adopted enough to delay the emergence of insecticide resistance, and should prompt if possible more decision from WHO recommendation of 5AIGRNG micro-encapsulated insecticide paint for a widespread use against Aedes species in Nigeria.

Index Terms- 5AIGRNG. Micro-encapsulated paint. Time-Mortality. Aedes Mosquitoes. Selected communities.

I. INTRODUCTION

The burden of these disease (dengue, yellow fever, chikungunya, and zika virus) is highest in tropical and sub-tropical areas and they disproportionately affect the poorest population. Since 2014, major outbreaks of Dengue, Malaria, Chikungunya, Yellow fever and Zika have afflicted populations, claimed lives, and overwhelmed health care system in many countries of the world [WHO, 2020, Lounibos, 2009].

The dengue virus was isolated from human sera in West Africa between 1960s and 1970s. Specifically, the dangerous virus was first isolated in Ibadan, Western Nigeria in 1960 [Fagbami et al., 1977]. It is likely that, many outbreaks of dengue may have been neglected, unrecognized, or under-reported due to a lack of awareness of health staff and unavailability of diagnostic tools in health institutions [Baba, and Talle, 2011].

Arbovirus are widespread in Nigeria considering that, the mosquito vectors responsible for the transmission of dengue, yellow fever, chikungunya (Aedes spp) and those responsible for malaria (Plasmodium spp) are well established in this country. Dengue are co-infection with other arbovirus infections, is therefore not uncommon and has been described in Nigeria [Gould et al., 2017]. These co-infections might provide an opportunity for exchange of genetic

materials and mutations resulting in the emergence of disease serenity.

Early signs and symptoms of dengue are distinguishable from those of other tropical disease fever like malaria and typhoid. In Nigeria where malaria is highly endemic, most cases of febrile illness are likely to be treated as presumption malaria [Amexo 2004]. And that's why the study to determine time-mortality of *Aedes* mosquitoes in Nasarawa State to enhance policy for intervention as a way to reduce the widen burden this disease caused in human population.

II. MATERIALS AND METHOD

2.1.1 Study Area

Nasarawa State with thirteen (13) Local Government Areas (LGAs) and communities with health concern is centrally located in the middle-belt region of Nigeria. The state lies between latitude 7° 45' and 9° 25'N of the Greenwich meridian. It shares boundary with Kaduna state in the North, Plateau state in the East, Taraba and Benue states in the south while Kogi and the Federal Capital Territory (FCT) flank it in the west. Nasarawa State has a total land area of 26,875.59 square kilometer and a population of about 1,826,883 according to the 2006 National Population Census estimated with density of about 67 persons per square kilometer [NSG, 2019].



Fig 1: Map of Nasarawa State, showing local government areas with domicile communities.

2.1.2 Sample Structure

Six (6) Local Government Areas (LGAs) of Nasarawa State was randomly selected (two each from senatorial zone) and thirty houses (five per LGA) were randomly selected and 5AIGRNG Micro-encapsulated emulsion paint was used as a trial paint

on the plaster cemented walls under laboratory condition.

2.2 Techniques

Mosquito Larval Sampling

- Mosquito Larval Sampling was carried out for the period of three (3) days each month during the study and monitoring period at the located breeding sites.
- The larvae were reared to adult stage under laboratory condition 27°C and 80% HR). 2-3 days old mosquitoes were used to run the WHO cone bioassay testing and assessment on the painted walls, immersed and dried with micro-encapsulated.

2.3 Testing protocol for insecticidal paint (WHO cone bioassay).

2.2.1 Bio-efficacy assay with mosquitoes.

- To assess the efficacy of 5AIGRNG insecticidal paint against *Aedes* species knockdown and mortality of surface treated walls under laboratory condition.



Fig 2: Sampling larval trays with larvae, reared to adult mosquitoes under laboratory conditions

2.3 Method

- The testing method follows the guidelines for mosquito adulticide for indoor residual spraying: (<http://apps.who.int/ins/bitstream/10665/69296/1/WHO-CDS-NTD-WHOPEP-GC-DPP-06.3-ng.pg14>) [26].
- Insecticide paint: 5AIGRNG (white)
- Biological material: Aedes mosquitoes from susceptible laboratory colony and wild strained obtained from first generation of field collected larvae.
- Substrates: Plaster cemented walls under laboratory condition
- Dose: Cement –
A – 8m²/l
B – Two layers of regular paint and second layer with insecticide paint at 8m²/l (paint density 1.4g/cm³).

2.3.1 Procedure

- Application: Brushing the surface with the required paint quality according to the dose and substrate size and type which was allowed to dry at room temperature for 7 days.
- Exposure: After which 10 non-blood fed females of the mosquito 2 to 5 days old were release in the cone chamber that is attached to the treated surface for 30minutes. Tested material were placed vertically. At this time, mosquitoes are removed from the cone and were placed in a clean paper cup with sucrose solution to prevent starving.
- Control: Though, the assay was also performed with the same procedure but with a regular paint.
- Replicates: 4

III. RESULT

Aedes spp abundance in selected communities of Nasarawa State, Nigeria.

Dengue have afflicted population in some part of Nigeria and the outbreak prompted this research work, indicative of hidden burden in people harboring the infection without knowing. Dengue has emerged as an important disease in Nigeria today which has attracted and calls for research,

surveillance and enhance vector intervention using 5AIGRNG micro-encapsulation inesfly emulsion paint to determine time-mortality of Aedes mosquitos' susceptibility, the cause of dangue fever. In these selective communities of Nasarawa State, table 1 showed Aedes spp larvae abundance in rain water puddles, west lands, tree holes, water storage containers, tires, septic tanks, gutters and drains, of all the larval source habitat, time-mortality of Aedes mosquito was measured in minutes and were recorded at each of the time interval (30m, 1hr, 24hr, 48hr and 72hrs respectively). At this, the wall cone bioassay were mounted at height variance of 0.5m, 1.0m and 1.5m, strictly adhered to the WHO instruction.

The adult insecticide bioassays conducted on Ae aegypti, revealed the effectiveness of the cone bioassay time-mortality from the rain water puddles at 30m and showed resistance in cone 1 and 2 (70%resistance and 80%resistance), but 98% susceptible susceptibility was observed in cone 3 but, after 24hrs of post-exposure, 100% susceptible susceptibility was achieved. This outcome were similarly observed of Aedes spp collected from the west lands, tree holes, water storage containers, and tires with resistance in content (Cone 1, 2 & 3), on the trial test at 30m, septic tanks, gutters and drains were 100% susceptible susceptible at 1hr and 24hrs respectively.

Time–mortality at 30m, showed a strong 70%resistance resistance of Ae albipictus mosquitoes and 80%resistance at 1hr of interval, and making up to 100% susceptible susceptible at 24hrs post-exposure of the emulsify inesfly micro-encapsulated paint across all the larval source habitat. The individual cone bioassay showed resistance in Ae albipictus spp collected from the rain water, and west lands, but at 0.5m height of Ae albipictus collected from the tree holes was 98% susceptible susceptible at 1hr while other larval source habitat, water storage containers (85%resistance), tires (75% resistance), septic tank (80%resistance), gutter and drains (80%resistance) were equally resistance in all the three (3) trial test of the cone bioassay at 30m, and 1hr respectively. And at 0.5m, 1.0m, and 1.5m height, all were susceptible after 24hrs of post-exposure to the micro-encapsulated paint wall

treatment (table 1). Susceptibility to *Aedes* mosquitoes larvae especially from the gutters and drains is indicative of the source habitat considered toxic accumulates concentrate which impact and quicken susceptibility of *Ae albopictus* (100% susceptible), hence there is no better drainage system structured in these communities to outlet

waste through the channel. Most fevers experienced may co-habit malaria and dangué, or yellow fever due to lack of awareness, knowledge about the disease, or negligence and under recognizing the hidden burden of yellow fever in person's suffering from the illness.

Table 1: *Aedes* mosquito abundance and distribution of larval source habitat in some communities of Nasarawa State, Nigeria

	Wall Cone bioassay parameters	Rainwater puddles	West lands	Tree holes	Water storage containers	Tires	Septic tanks	Gutters & Drains	30m	1hr	24hrs
		30m 1hr 24hrs	30m 1hr 24hrs	30m 1hr 24hrs	30m 1hr 24hrs	30m 1hr 24hrs	30m 1hr 24hrs	30m 1hr 24hrs			
<i>Aedes</i> spp		% % %	% % %	% % %	% % %	% % %	% % %	% % %	%	%	%
	Cone 1: 0.5m	70 80 100	50 70 100	50 90 100	80 95 100	80 100 100	90 100 100	75 95 100	0	0	0
<i>Aedes</i>	Cone 2: 1.0m	80 95 100	90 100 100	85 95 100	80 90 100	95 100 100	88 97 100	89 97 100	0	0	0
<i>aegypti</i>	Cone 3: 1.5m	98 100 100	97 100 100	99 100 100	90 100 100	99 100 100	9 100 100	99 100 100	0	0	0
	Cone 1: 0.5m	50 75 98	64 84 100	68 98 100	70 85 100	66 75 100	75 80 100	67 80 100	0	0	0
<i>Aedes</i>	Cone 2: 1.0m	68 88 100	74 80 99	78 90 100	76 89 100	69 89 100	60 85 100	84 90 100	0	0	0
<i>albopictus</i>	Cone 3: 1.5m	50 69 98	70 82 98	80 95 98	67 78 99	70 85 99	66 78 98	75 89 99	0	0	0

spp= species, m=minutes, hr=hour, &= and, %=percentage

The field trial conducted from February–August, the residual activities of micro-encapsulated insecticide paint follow strictly WHOPEs standard guideline, and the efficacy of the formulated product was expressed in time–mortality of 100% susceptible susceptibility of *Aedes* spp mosquitoes at 0.5m, 1.0m, and 1.5m height as a measure of acceptable knockdown possibilities. In a template, figure 3, showed an estimated frequency of *Ae aegypti* which determined knockdown mortality and at 30m of cone bioassay 1, 70% resistance was observed with 80% resistance at 1hr of time interval of larvae source from the rain water puddles though, in west lands there was a serious resistance observed at 0.5m height of 50% resistance and 70% resistance resistance, an indication of *Aedes* behavior towards height preference for bite. Tree holes had 50% resistance and 90% suspect, similarly from water storage containers with 80% resistance and 95% suspect meaning that, *Ae aegypti* required to adapt and get metabolize to enable susceptibility when at 1hr, larvae from tires and septic tanks were

susceptible (100% susceptible), gutters and drains yielded 95% suspect suspected resistance. In cone 2, larvae from west lands and tires showed high level of susceptibility (100% susceptible) with less few other larval source that showed resistance and more to be suspected at 30m and 1hr likely to be more desirous during bite and cone 3, the most preference 1.5m height at 1hr of knockdown, 100% susceptible susceptible was recorded across all larval source habitat (fig. 4 and 5).

For *Ae albopictus*, it varies with the mean estimated frequency of the formulated micro-encapsulated insecticide paint (5AIGRNG) measuring in time-mortality from February–August of the trial months of cone-bioassay after 24hrs post-exposure. This showed a strong variance between 0.5m, 1.0m and 1.5m height of measurement in all the months of study. At random, 98% susceptible, 99% susceptible, and 100% susceptible, ($\geq 98\%$ - 100% range) susceptibility was recorded from the bioassay formulated micro-encapsulated product with

properties capable to knockdown *Aedes albopictus* mosquitoes on a cemented treated wall. From the rain water puddles at 30m end-of-exposure, *Aedes albopictus* showed strong resistance with 50% resistance and 75% resistance at 0.5m height. Others from the west lands, water storage containers, tires, septic tanks, gutters and drains were similarly resistance with <90%, this shows that, they do not conform to climate change and adaptive capabilities, since they mostly are known to be adaptive to temperate climate though, from the tree-holes, 68% resistance killing effect was observed at 30m and 98% susceptible susceptible at 1hr of the 0.5m height proven exceptional. Even at 1.0m and 1.5m heights from all the larval source habitat, were observed to be ≤90% resistance (fig. 6,7,&8), this with far less killing effect might probably be, metabolic preceding the cause of resistance but susceptible at 24hrs of post exposure. Though, this assertion can be verify by molecular and metabolic absorbance strategic analysis to ascertain the resistance status of *Aedes albopictus* in Nasarawa state communities of studies.

For control, there was none knockdown of *Aedes* mosquitoes since, the wall cone-bioassay were mounted on a normal cemented plaster wall with no killing effect properties on the mosquitoes (Zero %). There was however, knockdown mortality decrease of mosquito density considering the effectiveness of the formulated product which from this findings, indicate a fast killing effect of the formulated micro-encapsulated insecticide paint.

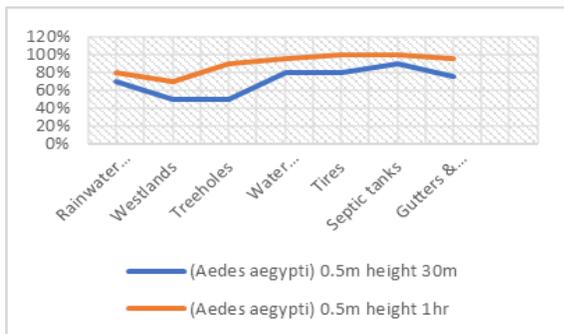


Fig 3, Cone 1: A histogram in time-mortality (%) of *Ae aegypti* from larval source habitat in six (6) Communities of Nasarawa State, Nigeria.

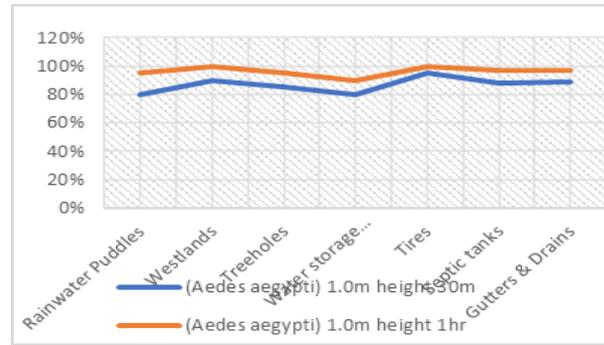


Fig 4, Cone 2: A histogram in time-mortality (%) of *Ae aegypti* from larval source habitat in six (6) communities of Nasarawa State, Nigeria.



Fig 5, Cone 3: A histogram in time-mortality (%) of *Ae albopictus* from larval source habitat in six (6) communities of Nasarawa State, Nigeria.

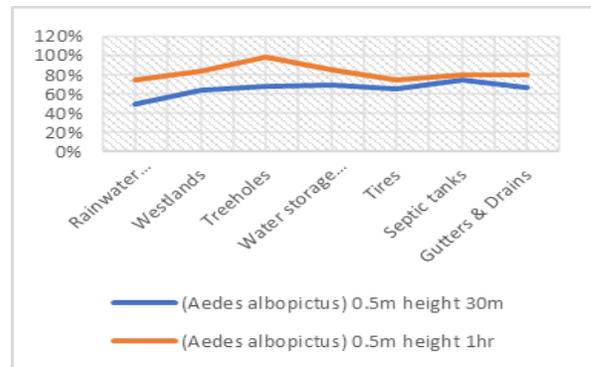


Fig 6, Cone 4: A histogram in time-mortality (%) of *Ae aegypti* from larval source habitat in six (6) communities of Nasarawa State, Nigeria.

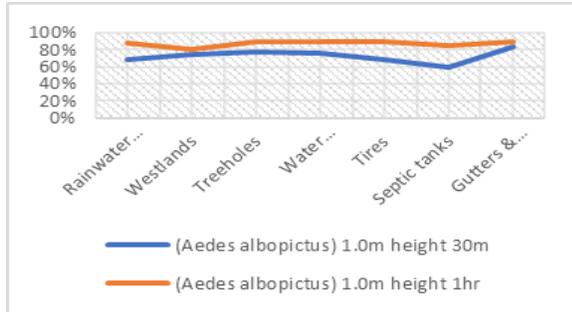


Fig 7, Cone 6: A histogram in time-mortality (%) of *Ae albopictus* from larval source habitat in six (6) communities of Nasarawa State, Nigeria.

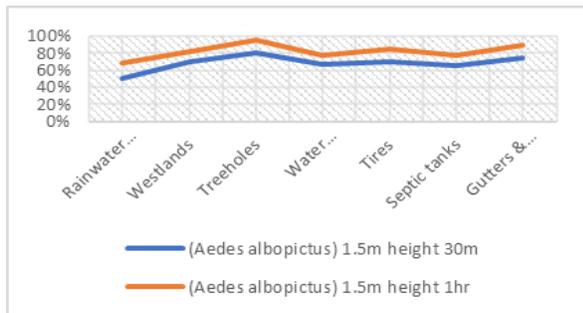


Fig 8, Cone 5: A histogram in time-mortality (%) of *Ae albopictus* from larval source habitat in six (6) communities of Nasarawa State, Nigeria.

3.2 Effect of climate and behaviour of *Aedes* spp mosquitoes in communities of Nasarawa State.

The effect of climate, efficacy and the residual activity of the micro-encapsulation of 5AIGRNG formulated product against wild population of the *Ae aegypti* and *Ae albopictus* were evaluated in six (6) communities of Nasarawa State located at North-Central, the middle-belt region of Nigeria which lies between latitude 7045' and 9025N' of the equator, and between longitude 70 and 90375'E of the Greenwich meridian. The six (6) communities of Nasarawa State, share boundaries with common economic values, and these communities have a dry tropical climate with the rainy season from March/April – October and 2,000mm of annual precipitation with wet and dry seasons, the dry season spans from November – March the sites however, are surrounded by houses, some with corrugated housing type as well some estate and few km into the next sources of larval habitat covering a total land area of 27,137.8sqkm of Nasarawa State (table 2).

Table 2: Climate and influence behaviour of *Aedes* spp. in some communities of Nasarawa State, Nigeria.

	Communities of Nasarawa State							Abundance Determined Factors.
	Keffi GPS: 8.8471° _N 7.8733° _E	Nas/Eggon 8.9066° _N 8.4084° _E	Kokona 8.8436° _N 8.0036° _E	Lafia 8.4939° _N 8.5154° _E	Nasarawa 8.5380° _N 7.7093° _E	Karu 8.8831° _N 7.5279° _E	Average Climate Reading.	
Rainfall (mm)	~1000-1200mm Low	~1,086mm	~950-1,200mm	~ 965-1645	~1,400-1,500mm	~1,00-1600mm	~1,230mm	Seasonal, & poor Waste management.
Temperature (°c)	~30.3°c (86.5° _F)	~27-30°c	27- 30°c	~26.7°c (80° _F)	27-30°c	27-3°c	27-30°c	Seasonal, & housing type.
Humidity (%-HR)	24% - 88% (Jan-Aug)	40%	40%	~73%-82%	80%	80%	40% - 88%	Seasonal, Climate & housing type.
Wind (4.7km/hr, peak in April)			in dry season season 80%	in rainy season season 39%-49%	in rainy season season 40%	in rainy season season 40%	Peaking rainy season	

Legend: Nas/= Nasarawa Spp.=Species °c = Degree centigrade north/east ~ = Aproximate GPS = Global Positioning System.

The GPS of each LGAs of Nasarawa State, requires an exploration of ecological, climate, socio-economic, and public health factors (fig. 9). The climatic factors is defined by rainfall (mm), temperature (°C), and humidity (%). In Nigeria, their

presence and impact are significant due to favorable tropical conditions and increasing urbanization. The geographic and climatic characteristics in all the LGAs help to understand why the abundance of wild population of *Aedes* spp mosquitoes in these

identified sources of larval habitat of Nasarawa State: Keffi is urbanized, semi-arid with high population density unlike Kokona which is a mixed urban- rural, agrarian, with moderate rainfall. Nasarawa Eggon is a highland, moderate temperature and the community is rural/agrarian while Lafia the capital city is the administrative center, with high urbanization though, Nasarawa is a riverine area with hot humid and share boundaries with Keffi and Karu a peri-urban, fast growing due to proximity to Abuja therefore, these diverse ecologies lead to variation in mosquito populations, breeding behaviors and disease transmission risk, Nasarawa State has had periodic yellow fever outbreaks, notably areas like Lafia,

Nasarawa Eggon, Kokona and unvaccinated populations in rural areas are particularly vulnerable.

However, the behaviour and impact of *Aedes* mosquitoes in Nasarawa State vary significantly by LGA, influenced by climate, urbanization and socio-economic practices. Urban LGAs like Keffi, Karu and Lafia face greater risks due to higher human population densities and artificial breeding sites, which rural LGAs experience seasonal peaks and potential zoonotic interactions. Strategic LGA specific interventions are needed to reduce the burden of *Aedes* – borne disease.

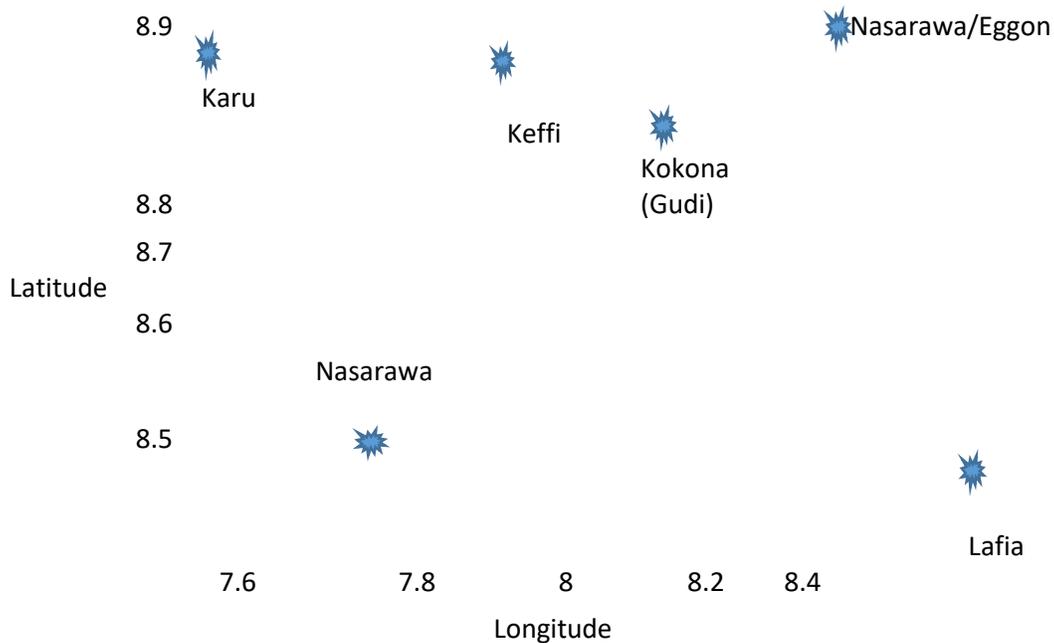


Fig. 9: Map showing the approximate GPS locations of communities (LGA'S) in Nasarawa State, Nigeria.

3.3 Monthly susceptibility of *Aedes* spp in communities of Larval Source habitat, Nasarawa State

Estimated frequency of 5AIGRNG micro-encapsulated insecticide paint was measured in time interval of *Ae aegypti* (fig.10). The histogram revealed the monthly distribution of the effective susceptibility of *Ae aegypti* from February – August, indicating 100% susceptible at 0.5m,

1.0m, and 1.5m height as it was observed mainly after 24hrs post-exposure across the period of observation. The gradient of the micro-encapsulated insecticide as measured in mean percentage (%) showed various frequencies in the susceptible gram. For *Ae albopictus* the frequencies was less in

metabolic absorbance than in the *Aedes aegypti* though, quite susceptible to the insecticidal paint at variant (standard = $\geq 98\%$ susceptible - 100% susceptible, while suspected $\geq 90\%$ suspected - 97% suspected, and Resistance $\leq 90\%$ resistance), table 11.

Ae aegypti mosquitoes generally from this study have shown 100% susceptible to 5AIGRNG micro-encapsulated insecticide and *Ae albopictus*, in some months varied in mean percentages at 0.5m height with 98% and 100% at 1.0m height. Moreso, 98% susceptible at 1.5m in all the heights after 24hrs of post-exposure, was recorded in the month of February. Similarly across all heights in March, there was 100% susceptible, 99% susceptible and 98% susceptible. Observation from April-July, *Ae albopictus* were at variant at 0.5m and

1.0m than at 1.5m across the months of studies except in June at 0.5m height and 80% resistance was read while at 1.0m was 85% resistance with 78% resistance at 1.5m in all, with worst resistance state of the month. In August, at 0.5m height, 99% susceptible was susceptible though, fall within the acceptable range of susceptibility ($\geq 98\%$ -100% susceptible) most probably, the less preference height for biting *Aedes* unlike the *Anopheles* spp mosquito population who have developed for years different strain as a result of pesticides that most have inflicted the very large environment and wide scale of impact on mosquitoes resistance to certain choices of insecticide, making it very difficult for vector control management and strategy for a national vector control intervention (fig.11).

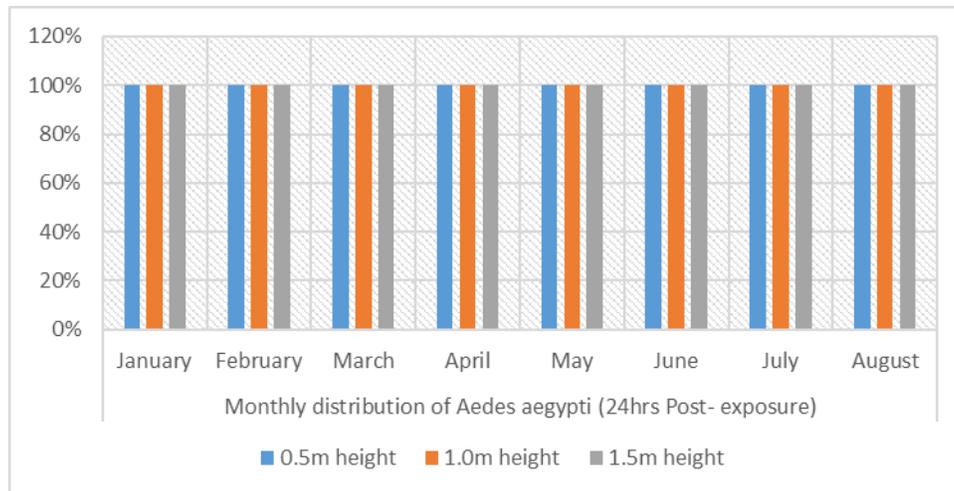


Fig. 10: Monthly estimated frequency (100%) of 5AIGRNG micro-encapsulation insecticidal paint for time-mortality of *Ae aegypti* after 24hrs Post-exposure in communities of Nasarawa State, Nigeria

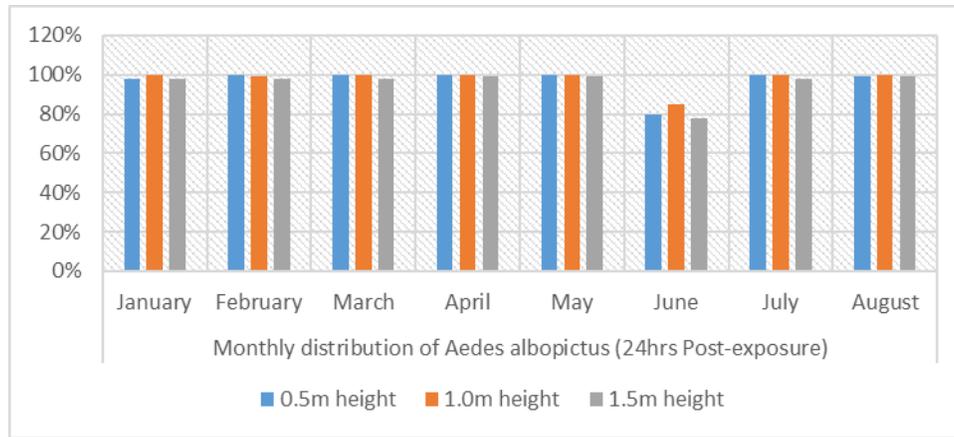


Fig. 11: Monthly estimated frequency (% variance) of 5AIGRNG micro-encapsulation insecticidal paint for time-mortality of *Ae albopictus* after 24hrs Post-exposure in communities of Nasarawa State, Nigeria.

DISCUSSION

The burden of dengue virus disease infection becomes worrisome and complicated to quickly detect dengue or yellow fever which have claimed lives and gradually get to overwhelm the health care systems in Nigeria. Infection is believe with any of the dengue virus subtypes to result either in an asymptomatic infection or febrile illness of varying severity [Gubler, 2022], as it was seen to manifest hemorrhagic fever in 10% of malaria patients in Ibadan [Amexo, 2004] and of most recently the outbreak in Sokoto and now in Edo State of Nigeria. The hidden burden reveals co-infections of dengue and malaria in Nigeria to provide the opportunity to determine 5AIGRNG micro-encapsulation in inesfly emulsion paint to determine time-mortality of *Aedes* spp, the causative vector of dengue in Nasarawa State. Insecticide resistance in Nigeria have long been performed but little work is been done on *Aedes* spp of mosquito populations in Nigeria. *Aedes* spp distribution in Nasarawa State have a profile of identified larval habitat, *Aedes aegypti* and *Ae albopictus* spp were morphologically identified using 'konus #5024 10x-30x LCD Digital Microscope Digiscience'.

The findings in this present study provides knowledge on the insecticide resistance profile which will provide vector control strategy to implement as a policy. Findings showed full susceptibility and variance in resistance of *Ae aegypti* and *Ae*

albopictus mosquito populations' trial tested with 5AIGRNG micro-encapsulated inesfly paint (a formulated product). Vontas et al., 2012 revealed from the previous studies that, a relative susceptibility was observed of this mosquito species to pyrethroids though there was resistance observed in *Ae. albopictus* in most of the trial test, this rapid expansion of resistance in *Ae. albopictus* could result from domestic or organic pollutants [Wilke et al., 2020] as this species is widely distributed in rainwater puddles, west lands, tree holes, tires, water storage containers, septic tanks, gutters and drains hence, considered toxic waste accumulates. The emergence of human arboviral disease such as the dangue fever was believed to have created a better adaptive condition as was observed by the ease of expansion of *Ae. Aegypti* and *Ae. Albopictus* creating a conducive conditions for the emergence [Leta, 2018].

But, in present studies a mosquito of arboviral disease, in its distribution had the ability to adapt to climate change and possible new environment. About the distribution of the main vectors that are involve in communities of Nasarawa State justified for lack of information, or knowledge about the adaptive ability to climate change, this clearly showed a synonym in *Ae. albopictus* in its ability to globally adapt to climate change and new environment [Knudsen, 1995., Medlock, 2012., and Bonizzoni, 2013]

However, the micro-encapsulated 5AIGRNG formulated product impact on *Ae. aegypti* and *Ae. albopictus*, achieving 100% at 24hrs post-exposure was among the *Ae. aegypti* species, and 98% - 100% susceptibility in *Ae. albopictus* from across the larval source habitats. This in fig. 1, 2, showed a mean estimated frequency of 5AIGRNG insecticidal paint in time-mortality of *Ae. aegypti* and *Ae. Albopictus*, where 100% susceptibility was obtained in *Ae. aegypti* while *Ae. albopictus* with variance between the range of 98% - 100% susceptibility after a 24hrs post-exposure with most host-seeking adult female *Ae. aegypti* and *Ae. albopictus* which were collected during the rainy season than the dry season.

Climate and influence behaviour of *Aedes* spp in the communities of Nasarawa State (Keffi, Nasarawa Eggon, Lafia, Nasarawa, Karu and Kokona), the Global Positioning System (GPS) gave a precision of latitude and longitude during the sampling period, the proximity to the GPS reading of both 0N and 0E gave a general affinities of climate related components friendly. Low rainfall in mm was recorded with~1000-1,200mm but relatively high in Lafia with~965-1,645m, Nasarawa (~400 – 150mm), and Karu (~1, 300 -1,600 mm) have an average climate reading of ≈1,230mm with conducive climate change and adaptive for insects and arboreal in the communities of Nasarawa State. The temperature recorded during the trial test do not show a much difference between~27-3.300C – 26.70C with the average of 270C - 300C except in Keffi with~30.30C i.e. 86.50F. Humidity in percentage (%) differs in months, as well in dry and rainy season where in Keffi 24%-88% was recorded from January to August and whether in the dry or rainy season fell within the range of 40% -80% humidity. These were notable determining factors for the abundance of *Aedes* mosquito in the communities, because of the seasonal poor waste management, housing type and climate, ease the distribution of this *Ae. aegypti* and *Ae. albopictus*. Though, it was obvious that, *Ae. aegypti* and *Ae. Albopictus* were found to be abundant equally in the dry and wet season as was the case in Yaunde, Camaroun [Chadee, 2013], and were exophagic and exophilic in behaviour.

Morphology and Ecology of *Aedes* mosquitoes in six (6) communities of Nasarawa state, Nigeria.

The morphology of *Aedes* mosquito from these communities of studies, the body size, being length, proboscis length, scale pattern, and sexual dimorphism in traits vary due to environmental pressures, such as climate, breeding sites, and availability of nutrients during the larval stage, and the ecological factors in the communities have varying ecological zones. Mousson et al., 2015 showed variation of *Ae. aegypti* competence for dengue virus transmission according to geographic origin and genetic diversity in Keffi and Karu communities which constitute the urban and semi-urban areas with high population densities and poor sanitation, ideal for *Ae. aegypti* breeding in artificial containers though, Nasarawa Eggon and Kokona are more rural, with natural breeding habitats like tree holes, puddles, and rock pools. Lafia the state capital, is an urban city with a mix of natural and artificial breeding grounds but, Nasarawa is a semi-rural community with the potential of both *sylvatica* and domestic *Aedes* spp though, co-researchers [Abdulraheem et al., 2002., Kamgang et al., 2012, Nasir et al., 2017, Brady et al., 2013] worked on spatial distribution and present certain ecological risk factors associated with *Aedes* mosquitos larval habitats in Kwara State of Nigeria and elsewhere to aligned with the probable environmental factors thought to influence variation of *Aedes* ecology which is defined in temperature, humidity, rainfall, vegetation and human activities, a major factor (Urbanization, and waste disposal) while Baba et al., 2013 provide evidence of the arbovirus infection in suspected febrile malaria and typhoid patients in Nigeria.

The key co-relation findings in this studies generally observed in ecological entomology, high temperatures produces urban heat islands which smaller body size of *Aedes* spp response due to rapid larval development, and nutrient-rich breeding sites in most of waste containers, attract larger body sizes and longer wings. Though, natural habitats with low disturbance (rural areas) make greater morphological diversity in terms of coloration, and size due to limited selection pressure [Briegel, 1990], and high larval density was seen common in urban areas with stunted growth due to competition, resulting in smaller adults. Similar scenario in Juliano 2009 findings, observed species interactions among larval

mosquitoes as a context dependence across habitat gradients while Reiskind et al., 2009, present the effects of intra-specific competition on adult longevity in the mosquitoes *Ae. aegypti* and *Ae. albopictus*.

In urban areas such as Keffi, Karu and Lafia likely host predominately *Ae. aegypti* with urban-adapted morphology which describe a darker, smaller size coloration, and a high vector competence but, the rural areas (Nasarawa Eggon, Kokona) may show more of a diverse *Aedes* species, with larger size and variable morphological traits due to more natural habitats, this translates to the ecology and demographic patterns of mosquito breeding in parts of Nasarawa State, Nigeria [Orita and Fannami, 2019], as well giving the Nigerian ecological studies background ease understanding the state development plan, environmental and ecological report [NSG, 2019., Wilke et al., 2020].

Though, in public health relevance, the morphology-ecology relationship usually affects vector competence when small mosquitoes may feed more frequently, increasing disease transmission, and where urban populations often show more resistance due to continuous exposure when surveillance and control, knowing where morphologically distinct populations exist helps tailor control strategies. However, there is a strong co-relation between the morphological traits of *Aedes* mosquitoes and the ecological conditions across Nasarawa State LGAs. Environmental factors shape the physical development and distribution of mosquito populations, influencing disease dynamics and control strategies.

Though, prolific vectors such as *Ae. aegypti* and *Ae. albopictus* have both established themselves in Nigeria. In the trend, their establishment has correlates most often with severe cases of dengue virus diseases. The human population however, is at risk, with dengue virus present in Nigeria, considering the gradual and rapid spread of dengue virus disease is partly due to closely related climates adaptive preferences of *Ae. aegypti* and *Ae. albopictus*. *Ae. albopictus* is known to be well adapted to temperate climate, currently spreading wide across the globe, whereas *Ae. aegypti* is better

adapted to more of tropical climate, thus, allowing *Aedes* to thrive well in all regions of the world [Colon-Gonzalez, et al., 2021].

In a similar manner from this findings, both *Ae. aegypti* and *Ae. albopictus* are well adapted to breed in selected man-made water containers, Gutters and drains, rain water puddles associated with urban settings in preference to clean water, and occasionally in turbid water as observed by Ahmed et al., [2022] where both species thrive in a clean water. The spread of dengue virus to have been fuelled by elements of unplanned urbanization [Gould et al., 2017, Baba et al., 2012], tires, inadequate waste water sources and water storage practices [Colon-Gonzalez, et al., 2021, WHO, 2017]. Now, if new products are to be adapted, considering the many successful vector control interventions in history that were progressively evaluated as they were rolled out on a programmatic basis [Killeen et al., 2017], will new product be adapted fast enough to delay the emergence of insecticide resistance? It is essential that review and recommendation policies take a bolder stance to emphasize pre-emptive action. If we continue waiting until we have all the evidence over need to be absolutely confident in our most important insecticide resistance management decisions, they will always come too late [Killeen et al., 2017].

Therefore, this findings should now prompt a more decision of WHO recommendation for 5AIGRNG micro-encapsulation insecticidal paint for a wide spread adaption against cost and coverage.

Acknowledgments

Thanks to the insectary and laboratory staff for every assistance.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Yako Andrew Bmibmitawuza: Methodology, writing – original draft, Writing – review & editing.
Sylvia Nwamaka Iroshe: Resources.
Sunday Igboanugo Iwunor: Resources.

REFERENCES

- [1] Abdulraheem, M., Yusuf, A.A., Adebayo, A.M., and Sam-Wabo, S.O. (2002). Spatial distribution and Ecology Risk Factors Associated with Aedes Mosquitoes Larval Habitats in Kwara State, Nigeria. *Parasite and Vectors*, 13(1), 1-10. <https://doi.org/10.1186/s13071-020-04368-3>.
- [2] Ahmed A., Irish S.R., Zohdy S., Yoshimizu M., Tadesse F.G. 2022: Strategies for Conducting Anopheles Setepheni Surveys in Non-Endemic Areas. *Acta Tropical*, 236:-10671.
- [3] Amexo M, Tothurst., Barnish G., Bates., (2004). Malaria Misdiagnosis: Effect on the Poor and Vulnerable. *The Lancet*, 364i 1896-8.
- [4] Baba M.M., and Talle M. (2011). The Effect of Climate on Danguue Virus Infections in Nigeria. *New York Science Journal*, 4:28-33.
- [5] Baba M., Villinger J., Masiga D. K. 2012: Repetitive Dengue Outbreaks in East Africa: A Proposed Phased Mitigation Approach may reduce its impact. *Reviews in Medical Virology*, 26(3), 183-196.
- [6] Baba M., Logue C.H., Oderinde B., Abdumalik H. 2013: Evidence of Arbovirus Co-Infection in Suspected Febrile Malaria and Typhoid Patients in Nigeria. *The Journal of Infection in Developing Countries*, 7 (01), 051-059.
- [7] Brady O.J. Gething P.W., Bhatt S., et al., 2013: Refining the Global Spatial Limits of Danguue. *Nature*. 496:504-07.
- [8] Briegel H. 1990: Metabolic Relationship Between Female Body Size, Reserves, and Fecundity of Aedes aegypti. *Journal of Insect Physiology*, 36(3), 165-172.
- [9] Bonizzoni M., Gosperi G., Chen X., James A.A., et al. 2013: The Larvasive Mosquito Species Aedes albopictus Current Knowledge and Future Perspective. *Trends in Parasitology*, 29(9), 460-468.
- [10] Colon-Gonzalez F.J., Swe M.O., Tompkins A.M., et al. 2021: Projecting the Risk of Mosquito-Borne Disease in a Warmer and More Populated World; A Multi-Model, Multi-Senaria Intercomparison Modelling Study. *Lancet Planet Health*. 5:e404-14.
- [11] Chadee D.D. 2013: Resting Behaviour of Aedes aegypti in Trinidad: With Evidence for Sthe Re-Introduction of Indoor Residual Spraying (IRS) for Dengue Control. *Parasites and Vectors*, 6,255.
- [12] Gould E., Pettersen .J., Higgs S., Charrel R., de Lamballerie X. 2017: Emerging Arboviruses Why Today? *One Health*. 4:1-13.
- [13] Gubler, D.J. 2022: Epidemic Danguue/Dengue Hemorrhagic Fever as a Public Health, Social and Economic Problem in the 21st Century. *Trends Microbiology*, 10,100-103.
- [14] Juliano S.A. 2009: Species Interactions Among Larval Mosquitoes: Context Dependence Across Habitats Gradients. *Annual Review of Entomology*, 54(1), 37-56.
- [15] Kamgang B., Marcombe S., Chandre F., Nchoutpoven E., Etang J., Poupardin R., and Simard F. 2012: Geographic Distribution and Larval Habitat Characteristics of Aedes eagypti and Aedes albopictus in Central Africa. *Parasites and Vectors*, 5, 327.
- [16] Killean G.F., Tatarsky A., Diabate et al. 2017. Developing an Expanded Vector Control Tool Box for Malaria Elimination. *BMJ Global Health* 2; e000211.
- [17] Knudsen A.K., Allebeck P., Tollanes M.C., 1995. Life Expectancy and Disease Burden in Nordic Countries: Results from the Global Burden of Diseases Injuries, and Risk Factors Study 2017, *The Lancet Public Health*, 4(12), e658-e669.
- [18] Leta S., Beyene T.J., De Clerq. E.M, Amenu K. 2018. Global Risk Mapping for Major Disease Transmitted by Aedes aegypti and Aedes albopictus, *International Journal of Infectious Disease*. 67, 25-35.
- [19] Lounibos, 2009. Insects and Allies Associated with Bromiliads: A Review, *Terrestrial Arthropod Reviews*. 1(2), 125-153.
- [20] Medlock J.M., Hansford K.M., Scaffner F. et al., 2012: A Review of the Invasive Mosquitoes in Europe: Ecology, Public Health Risks, and Control Options, *Vector-Borne and Zoonotic Diseases*, 12(6), 435-447.
- [21] Mousson L., Dauga C., Garrignes T., et al. 2015: Phylogeography of Aedes (Stegomyia)

- aegypti (L) and *Aedes (stegomyia) albopictus* (skuse) (Diptera:culicidae) Base on Mitochondrial DNA Variations.
- [22] Nasarawa State Government, 2019. State Development Plan: Environmental and Ecological Reports. Nasarawa State Ministry of Environment. Nasarawa State Government Official Publications or Ministry of Environment.
- [23] Nasir I.A., Agbede O.O, Dangana A., Baba M., Haruna A.S. 2017: Dengue Virus Non-Structural Protein-1 Expression and Associated Risk Factors among Febrile Patients Attending University of Abuja Teaching Hospital Nigeria. *Virus Research*, 230, 7-12.
- [24] Oditia F.A, and Fannami M.Y. 2019: Ecological and Demographic Patterns of Mosquito Breeding in Parts of Nasarawa State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 23(5), 877-882.
- [25] Reiskind M.H., and Lounibos L.P. 2009: Effects of Intraspecific Competition on Adult Longevity in the Mosquitoes *Aedes aegypti* and *Aedes albopictus*. *Medical and Veterinary Entomology* 23(11), 62-68.
- [26] [27]Testing Method: http://app.who.int/iris/bitstream/10665/69296/1/WHO_CDS_NTD_WHOPEP-CrC-GC-DPP-2006-3-eng.pdf
- [27] [28]Vontas J., Kioulos E., Palvidi N., Morou E., Torre A.D., Ranson H. 2012: Insecticide Resistance in the Major Dengue Vectors *Aedes albopictus* and *Aedes aegypti*, *Pesticide Biochemistry and Physiology* 104(2): 126-131.
- [28] Wilke T., Hauffe T., Jovanoska E., Cretkoska, Timme, 2020: Deep Drilling Reveals Massive Shifts in Evolutionary Dynamics After Formation of Ancient Ecosystem. *Science Advances*, 6(40), eabb2943.s
- [29] World Health Organization, (2017). *Vector Surveillance and Control at Ports Airports and Ground Crossing: A Manual for Use by National Authorities and Health Workers*. WHO.
- [30] Fagbami A.H., Monath T.P., Fabiyi A. 1977: Dengue virus infections in Nigeria: a survey for antibodies in monkeys and humans. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, vol 71, issue1, 60-65.
- [31] World Health Organization, 2020: Dengue and severe dengue. [Accessed 26 August 2020]. Available at: <https://www.who.int/news-room/fact-sheets/detail/dengue-and-servant-dengue>.
- [32] World Health Organization, 2017. *Comprehensive Guidelines for Prevention and Control of Danguue and Dange Hemorrhagic Fever*. Revised and Expanded Edition 2017. <https://apps.who.int/iris/bitstream/handle/10665/204894/B4751.pdf?sequence=1&isAllowed=y> (accessed.oct.5,2022).