Post-Decade Ivermectin Compliance and Entomological Assessment of Onchocerciasis in Inyele District, Olamaboro LGA, Kogi State, Nigeria

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Abstract
Onchocerciasis, commonly referred to as river blindness, poses a significant health challenge, particularly in sub-Saharan Africa. Despite decades of Ivermectin administration via the mass drug administration (MDA) strategy, this neglected tropical disease persists in many regions, including parts of Kogi State. Hence, assessing Ivermectin compliance and conducting entomological surveys in Olamaboro LGA of Kogi State, Nigeria, is necessary. This study administered structured questionnaires to residents of selected communities to measure Ivermectin compliance, captured and dissected Simulium spp., and further detected the presence of Onchocerca larvae in these flies. The results of this study revealed 90.8% compliance with Ivermectin, with residents reporting complete compliance (100%) in Ubalu Community, 93% compliance in Ogoh Inyele Community, and 80.5% in Uloko Community. Statistical analysis revealed no significant difference between participants' socio-demographics and their compliance with Ivermectin. Furthermore, 113 blackflies were captured, and 31% of them were confirmed parous. Morphological identification revealed that none (0%) of the blackflies harboured Onchocerca volvulus larvae. With the high Ivermectin compliance rates and the absence of infected vectors in this study, the ongoing transmission of this disease is confirmed to be suppressed. However, there is a need to ensure continuous Ivermectin MDA and encourage high community participation to achieve the elimination deadline set by the World Health Organisation by 2030.

Keywords: Onchocerciasis, Simulium spp., Entomological survey, Ivermectin compliance, Neglected tropical Disease

Introduction
Onchocerciasis, commonly referred to as river blindness, is a neglected tropical disease (NTD) that causes a significant public health challenge in various parts of the world (Chikezie et al., 2023). This disease is characterized by several irreversible complications, including blindness, depigmentation of the skin, dermatitis, and debilitating itching. It results from an infection caused by the parasitic filarial nematode, *Onchocera volvulus*. This parasite is transmitted via bites from infected black flies (*Simulium* species). The transmission vector for onchocerciasis is quite abundant in areas with swift-moving rivers and rocky vegetation, which provides *Simulium* species with an ideal breeding environment (Surakat et al., 2018; Ouedraogo et al., 2024).

The aetiology of the infection is characterized by the spread of adult female worms throughout the connective tissues beneath the skin. Then, the viviparous filaria gives birth to thousands of larval worms or microfilariae. Microfilariae migrate into the skin and the eye, causing damage to these organs as they die, resulting in terrible itching and ocular lesions. After repeated years of exposure to microfilariae, these lesions can result in irreversible disability (Hill et al., 2019; Chikezie et al., 2023). Blackflies ingest the parasite through a blood meal, after which the microfilariae develop into their infective stage. Further disease transmission occurs from fly bites from the infected vector's next blood meal (Koala et al., 2019).

The World Health Organisation (WHO) reports that sub-Saharan Africa is home to 99% of the 26 million persons with onchocerciasis globally (Ouedraogo et al., 2024). The administration of Ivermectin has been a major treatment option aimed at eliminating this disease. Major control efforts from the Onchocerciasis Control Programme in West Africa (OCP) and the African Programme for Onchocerciasis Control (APOC) have aided in the decline in transmission levels. However, this disease remains persistent in various areas, especially sub-Saharan Africa (Stolk et al., 2021; Tirados et al., 2022; Jacob et al., 2024). Unfortunately, at the time of this study, Kogi State, particularly the Inyele District of Olamaboro local government area (LGA), lacks current information on Ivermectin compliance and entomological evaluations of onchocerciasis in accordance with the WHO guidelines and recommendations for the complete eradication of onchocerciasis by 2030 (WHO, 2023). Thus, the purpose of this study is to evaluate the seroprevalence and entomological surveillance of onchocerciasis across three selected communities of Inyele District of Olamaboro LGA in Kogi State, following over a decade of Ivermectin MDA.

Materials and Methods
Study Area
The study was conducted across three recorded endemic communities: Ogoh Inyele, Ubalu, and Uloko, all located along River Wonderful in Inyele District, Olamaboro LGA, Kogi State. Blackflies were captured from selected riversides in these communities: Egane River (Inyele Ogoh), Opata River (Ubalu), and Uloko River (Uloko). Olamaboro LGA (Figure 1) is located in southeast Kogi State, sited between coordinates 7°11′N 7°34′E, characterised by an average elevation of 301m, a minimum elevation of 104m, and a maximum elevation of 537m above sea level. It has an estimated population density of 190.3/km2 and an area of 1,123 km^2 (City Population, 2022).
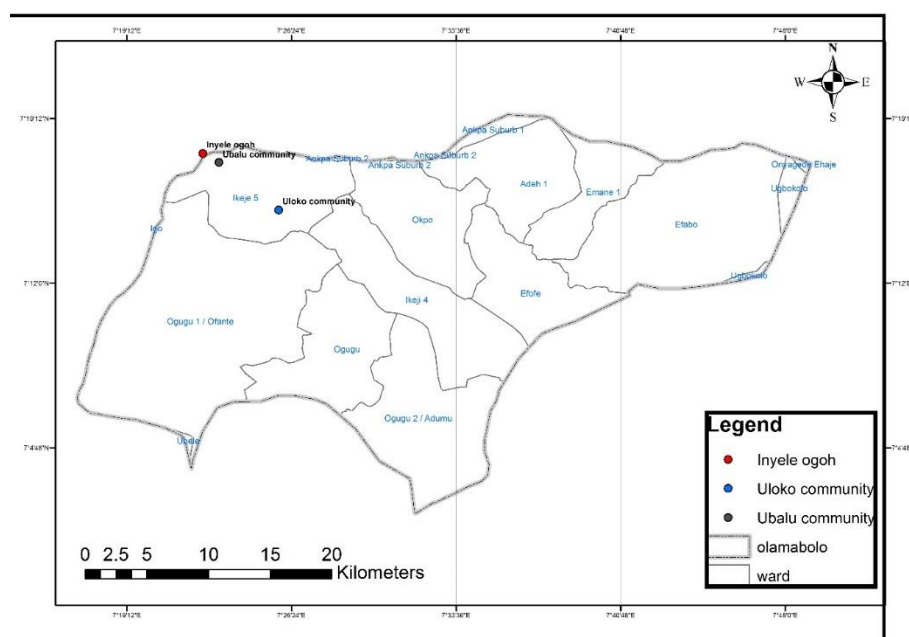

Figure 1: Digital Map Showing the Study Areas in Olamaboro LGA of Kogi State

Study Design
Entomological assessments were conducted using human landing collection. Furthermore, structured questionnaires were used to evaluate Ivermectin compliance of residents across these first-line villages (Arega et al., 2023).

Ivermectin Compliance Data
Questionnaires were issued to permanent inhabitants of the selected first-line communities. Specific Ivermectin compliance information were obtained from willing participants. This structured survey was used to obtain details of participants' level exposure to black flies, likely symptoms of onchocerciasis, compliance and frequency of Ivermectin usage, presence of any adverse effect of the drug, and if they have been skin snipped before (Arega et al., 2023). Informed consent was obtained from participants prior to the interview. The questionnaire was administered in English and divided into two (2) parts: the Biodata Section and the Main Section.

Entomological Assessment
The entomological assessment was conducted from July to September 2024 across rivers within the selected study area in Kogi State.

Collection and Preservation of Blackflies
Adult female *Simulium* spp. were captured using human baits. For this, two flycatchers were stationed in Egane River (Inyele Ogoh), Opata River (Ubalu), and Uloko River (Uloko); they took alternate positions for one hour between 07:00 and 18:00. The collection took place twice every two weeks for two months. The collected vectors were kept in sterile plastic tubes with water-drenched cotton (to keep them alive) (Koala et al., 2019; Oyinloye et al., 2024).

Identification of Blackflies
The collected vectors were subjected to proper morphological identification using standard keys to confirm that they were *Simulium* spp. With the aid of a microscope, the blackflies were characterized based on the colour of the first four posterior antennal segments, the ninth abdominal tergite setae, the scutella setae, and the fore coxa colouration; the wing tufts (stem vein setae) were also inspected and graded on a 00–05 scale (Oyinloye et al., 2024).

Detection of *Onchocerca* Larvae through Blackflies Dissection
The identified blackflies were dissected using the method described by Oforka et al. (2020). Briefly, the ovaries of the female blackflies were dissected and stretched using sterile dissecting pins. Then, blackflies were categorised as nulliparous if they possessed non-stretchy ovaries, dense Malpighian tubules, and many fat bodies. Otherwise, these vectors were classified as parous if they had clear Malpighian tubules, decreased or nonexistent fat bodies, and stretchy ovaries. The parous black flies' head, thorax, and abdomen were meticulously dissected for various *O. volvulus* larval stages. The dissected blackflies identified as parous had their tissues teased apart and deposited in normal saline and carefully inspected for filarial parasites that were morphologically identical to *O. volvulus* larvae (Koala et al., 2019).

Data Analysis
Data analysis was conducted using the IBM Statistical Package of Social Sciences (SPSS) version 23. Pearson's chi-square test was used to determine the level of Ivermectin compliance amongst the population.

Results
Overall Community Compliance with the Ivermectin MDA Program
The questionnaire needed to measure the Ivermectin compliance rate was administered to a total of 314 persons across all three study areas, accounting for the adult population (18 – 75+ years). Results show that the overall compliance rate across the three selected study sites was 90.8%, indicating a significant implementation of the Ivermectin MDA program. The highest compliance was recorded in Ubalu (100%), followed by Ogoh Inyele (93%), while the least compliance was recorded in Uloko (80.5%). The result of the overall community compliance with the Ivermectin MDA program is presented in Table 1.

Table 1: Overall Compliance with Ivermectin Treatment across Selected Study Sites in Olamaboro LGA, Kogi State.

Community	Total Respondents	Compliant	Non-Compliant	Compliance Rate
Ogoh Inyele	100	93	7	93.0%
Ubalu	101	101	0	100%
Uloko	113	91	22	80.5%
Total	**314**	**285**	**29**	**90.8%**

Compliance with Ivermectin in Ogoh Inyele

This study revealed that 93 (93%) out of 100 respondents in the Ogoh Inyele community were compliant with Ivermectin MDA, while 7 (7%) were non-compliant. The community compliance with Ivermectin in Ogoh Inyele is presented in Table 4.4. Results show that the highest level of compliance was recorded in people within the age group of 66 – 77+ years (100%), and the lowest compliance rate was recorded in those within 18 – 25 years. Furthermore, 94.7% (36) of the males were compliant, while 91.9% (57) of the females were compliant. Also, 92.8% (90) of the natives of this community were compliant with Ivermectin MDA.

All participants took Ivermectin ≥10 years ago and received at least three rounds. Notably, 94% were treated in the past year, with 92.6% compliance. In this study, there was no significant association between socio-demographics and treatment history with Ivermectin compliance ($p > 0.05$).

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Table 4.4: Community Compliance with Ivermectin Treatment in Ogoh Inyele

Variable	Category	Total (%)	Compliance Status		Chi-Square	*p*-Value
			Compliant (%)	Non-Compliant (%)		
Age	18-25	14 (14%)	12 (85.7%)	2 (14.3%)	2.587	0.763
	26-35	24 (24%)	22 (91.7%)	2 (8.3%)		
	36-45	16 (16%)	15 (93.8%)	1 (6.3%)		
	46-55	19 (19%)	18 (94.7%)	1 (5.3%)		
	56-65	11 (11%)	10 (90.9%)	1 (9.1%)		
	66-75+	16 (16%)	16 (100%)	0 (0%)		
Sex	Male	38 (38%)	36 (94.7%)	2 (5.3%)	0.259	0.618
	Female	62 (62.6%)	57 (91.9%)	5 (8.1%)		
Origin	Natives	97 (97%)	90 (92.8%)	7 (7.2%)	0.233	0.629
	Residents (10+ Years)	3 (3%)	3 (100%)	0 (0%)		
Occupation	Students	4 (4%)	3 (75%)	1 (25%)	2.458	0.293
	Trading	6 (6%)	6 (100%)	0(0%)		
	Farming	90 (90%)	84 (93.3%)	6 (6.7%)		
Treatment History	Took First Ivermectin ≥ 10 Years Ago	100 (100%)	93 (93%)	7 (7%)		
	Taken At Least Three Rounds of Ivermectin	100 (100%)	93 (93%)	7 (7%)		
Treatment Within the Past Year	Yes	94 (94%)	87 (92.6%)	7 (7.4%)	0.480	0.488
	No	6 (6%)	6 (100%)	1 (0%)		

Compliance with Ivermectin in Ubalu

In this study, the participant responses revealed a complete (100%) Ivermectin compliance rate in Ubalu. The community compliance with Ivermectin treatment in this study area is presented in Table 2. Every respondent that participated in the survey across all socio-demographic and treatment history categories reported the use of this drug in the MDA program, with at least three rounds of the treatment. Due to the lack of variability in the outcome of the compliance status, the chi-square statistical test was not applicable.

Table 2: Community Compliance with Ivermectin Treatment in Ubalu

Variable	Category	Total (%)	Compliance Status	
			Compliant (%)	**Non-Compliant (%)**
Age	18-25	21 (20.8%)	21 (100%)	0 (0%)
	26-35	15 (14.9%)	15 (100%)	0 (0%)
	36-45	25 (24.8%)	25 (100%)	0 (0%)
	46-55	16 (15.8%)	16 (100%)	0 (0%)
	56-65	11 (10.9%)	11 (100%)	0 (0%)
	66-75+	13 (12.9%)	13 (100%)	0 (0%)
Sex	Male	40 (39.6%)	40 (100%)	0 (0%)
	Female	60 (60.4%)	60 (100%)	0 (0%)
Origin	Natives	101 (100%)	101 (100%)	0 (0%)
	Residents (10+ Years)	0 (0%)	0 (0%)	0 (0%)
Occupation	Students	9 (8.9%)	9 (100%)	0 (0%)
	Trading	13 (12.9%)	13 (100%)	0 (0%)
	Farming	76 (75.2%)	76 (100%)	0 (0%)
	Mechanic	2 (2.0%)	2 (100%)	
	Staff Nurse	1 (1.0%)	1 (100%)	
Treatment History	Took First Ivermectin 1-10 Years Ago	5 (5%)	5 (100%)	0 (0%)
	Took First Ivermectin over 10 Years Ago	95 (94.1%)	95 (100%)	0 (0%)
	Can't Recall Taking Ivermectin	1 (0.9%)	1 (100%)	0 (0%)
	Taken At Least Three Rounds of Ivermectin	95 (94.1%)	95 (100%)	0 (0%)
Treatment Within the Past Year	Yes	101 (100%	101 (100%	0 (0%)
	No	0 (0%)	0 (0%)	0 (0%)

Compliance with Ivermectin in Uloko

In Uloko, the Ivermectin MDA compliance rate was shown to be 80.5%, with 91 out of 113 respondents confirming their adherence to this treatment. The result of the community compliance with Ivermectin in Uloko is presented in Table 3. Complete compliance was recorded in the age groups 46–55 years and 56-65 years, respectively, while the least compliance was recorded for respondents ages 18- 25 (35%). Similarly, 84.3% of the respondents who were natives of the community were compliant, while only 45.5% of the residents reported to have adhered to the Ivermectin treatment.

This study further revealed the disparity of the compliance status across different occupations. While participants who were students reported complete compliance (100%), farmers, who made up a larger percentage of the respondent population, reported a compliance rate of 85.1%, and traders reported a lower adherence rate (52.9%). Considering the treatment history, this study underscores that participants who received Ivermectin treatment in the past year had a higher compliance rate (97.4%), while those who did not engage in this regimen last year had a lower adherence rate (45.9%). Across different variables, such as age, origin, and occupation, the compliance analysis revealed statistical significance ($p < 0.05$).

Table 3: Community Compliance with Ivermectin Treatment in Uloko

Variable	Category	Total (%)	Compliance Status		Chi-Square	*p*-Value
			Compliant (%)	Non-Compliant (%)		
Age	18-25	20 (17.7%)	7 (35.0%)	13 (65.0%)	43.194	0.000
	26-35	15 (13.3%)	9 (60.0%)	6 (40.0%)		
	36-45	16 (14.2%)	15 (93.8%)	1 (6.3%)		
	46-55	18 (15.9%)	18 (100%)	0 (0%)		
	56-65	16 (14.2%)	16 (100%)	0 (0%)		
	66-75+	28 (24.8%)	26 (92.9%)	2 (7.1%)		
Sex	Male	48 (42.5%)	39 (81.3%)	9 (18.8%)	0.028	0.868
	Female	65 (57.5%)	52 (80.0%)	13 (20.0%)		
Origin	Natives	102 (90.3%)	86 (84.3%)	16 (15.7%)	9.563	0.002
	Residents (10+ Years)	11 (9.7%)	5 (45.5%)	6 (54.5%)		
Occupation	Students	2 (1.8%)	2 (100%)	0 (0%)		
	Trading	17 (15.0%)	9 (52.9%)	8 (47.1%)	9.992	0.007
	Farming	94 (83.2%)	80 (85.1%)	14 (14.9%)		
Treatment History	Took First Ivermectin 1-10 Years Ago	17 (18.1%)	17 (100%)	0 (0%)		

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	Took First Ivermectin over 10 Years Ago	68 (72.3%)	65 (95.6%)	3 (4.4%)	1.185	0.553
	Can't Recall Taking Ivermectin	9 (9.6%)	9 (100%)	0 (0%)		
	Taken At Least Three Rounds of Ivermectin	92 (97.9%)	90 (97.8%)	2 (2.2%)	30.675	0.000
Treatment Within the Past Year	Yes	79 (67.3%)	74 (97.4%)	2 (2.6%)	41.970	0.000
	No	37 (32.7%)	17 (45.9%)	20 (54.1%)		

Blackfly Abundance and Prevalence of *Onchocerca volvulus*

A total of 113 blackflies were collected from July to September 2024 at a sampling rate of two days each week across the three selected study areas. Egane River in Ogoh Inyele had the highest distribution of blackflies (56), followed by Opata River Ubalu (43) and Uloko River (14). All specimens were further confirmed to be *Simulium* spp, following standard morphological analysis. The parity status of these blackflies showed that 35 were parous while 78 were nulliparous. This study also examined the presence of *O. volvulus* larval, revealing none (0) out of the 35 parous blackflies to be positive for *O. volvulus.* The results obtained for the relative abundance of blackflies, parity assessment, and *O. volvulus* detection are presented in Table 4.

Table 4: Relative Abundance, Parity Status, and Infection Rate of *Simulium* Blackflies Captured across All Three Study Sites.

Study Site	Number Collected	Parity Status		Infection Rate (%)
		Parous	**Nulliparous**	
Egane River (Ogoh Inyele)	56 (49.6%)	18 (32.1%)	38 (67.9%)	0%
Opata River (Ubalu)	43 (38.1%)	12 (27.9%)	31 (72.1%)	0%
Uloko River (Uloko)	14 (12.4%)	5 (35.7%)	9 (64.3%)	0%
Total	**113 (100%)**	**35 (31%)**	**78 (69%)**	**0%**

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Discussion

Onchocerciasis, a common filarial disease in tropical and subtropical regions, caused by the *Onchocerca volvulus*, remains the second leading cause of infectious blindness (Onojafe et al., 2022). Community-Directed Treatment with Ivermectin is the primary elimination strategy for onchocerciasis (Wanji et al., 2015). Despite significant control efforts, the disease remains persistent. In this study, community Ivermectin compliance and entomological surveys were assessed across communities in Olamaboro LGA. In evaluating community adherence to the Ivermectin MDA program, this study highlighted a significant adherence to control treatments. The overall compliance rate was 90.8% among the 314 adult respondents. In contrast to the 9.2% non-compliance rate observed in this study for Ivermectin treatment, Otabil et al. (2023) reported a 5% non-compliance rate in the Bono region of Ghana. The findings from that study associated the lack of adherence with fear of the drug side effects, pregnancy, and some challenges during drug distribution. This study revealed that Ubalu outperformed other communities, with a 100% compliance rate, while Uloko had the lowest compliance rate at 80.5%. Community participation remains a significant aspect that bridges the gap between MDA coverage and uptake. When a significant proportion of the population fails to participate in Ivermectin treatment, a potential reservoir of parasites remains untreated, creating an avenue for disease recurrence (Kumah et al., 2023). In a systematic review by Mitchell et al. (2022), the community perception and willingness to partake in mass drug administration programs are influenced by the social nature of these individuals' institutional and interpersonal influences.

The Ogoh Inyele, Ubalu, and Uloko communities of Olamabaro LGA in Kogi State are located near major rivers that serve as breeding sites for *Simulium* blackflies. Studies have shown that infected blackflies are responsible for resurging infections of onchocerciasis (Koala et al., 2019). In this study, the entomological survey recorded the collection of a total of 113 *Simulium* flies from July to September 2024. The fly density was highest in the Egane River and lowest in the Uloko River. The abundance of flies has been shown to be influenced by seasonal variation, which is not only linked to environmental conditions but also to ecological conditions. When flooded, breeding sites typically have low numbers of flies, and their numbers may gradually increase as the water recedes (Atekem et al., 2024). Additionally, Chikezie et al. (2023) noted that the distribution and population densities of black flies in the various study areas are significantly influenced by the availability of suitable aquatic habitats. The wet season in Kogi State generally begins from April to October; thus, the high relative humidity during the collection of the flies may influence the abundance (Olutimayin & Aribisala, 2020). The presence of abundant nulliparous blackflies aligns with the findings of Adeleke et al. (2010), who found more nulliparous flies across the Osun River basin. Contrary to the findings in this study, Chikezie et al. (2023) recorded a higher proportion of parous flies than nulliparous flies, suggesting that a low proportion of parous flies may indicate the presence of an active breeding site for young flies or reveal decreased fly longevity. This study further assessed the presence of *O. volvulus* larvae by dissecting the identified blackflies and found none present. The absence of onchocerca larvae in the flies sampled in this study may be linked to the high MDA compliance rate. Amaechi et al. (2024) highlighted that sustained Ivermectin compliance could decrease microfilaria prevalence and reduce the infection rates of blackflies.

Conclusion

In Olamaboro LGA, the study found a 7.8% seroprevalence of onchocerciasis. This indicates that the illness persists even after years of Ivermectin treatment. The highest seropositivity (25.8%) was found in those 70 years of age and older, while the highest positive result (51.6%) was found in females. Additionally, the study showed a high overall Ivermectin compliance of 90.8%, and the entomological analysis showed that the blackflies that were caught did not contain any *O. volvulus* larvae. Integrating the serological and entomological findings in this study can serve as a baseline for initiating effective strategies for onchocerciasis elimination in this region.

Recommendations

- There is need for regular monitoring schemes to assess the annual compliance with Ivermectin to ensure better intervention strategies.
- Improved health campaigns and community sensitizations, regarding Ivermectin MDAs are necessary, as such programs will enlighten members of these communities about the benefit of the drugs and clear certain misconceptions regarding such therapy.
- Further expansion of post-treatment surveillance is needed, alongside active collaborations with different social groups to encourage MDA compliance.

- Enhanced vector surveillance is needed to confirm the interruption of onchocerciasis transmission across different seasons, expanding to neighbouring communities and LGAs to detect the potential for disease reintroduction.

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