

Original Research Article

**PHYSICO-CHEMICAL ASSESSMENT OF *SIMULIUM DAMNOSUM*
THEOBALD COMPLEX IN OJI RIVER BASIN, ENUGU STATE
NIGERIA**

ABSTRACT

Aims: Black flies of the *Simulium damnosum* complex are the principal vectors of *Onchocerca volvulus*, the causative agent of Onchocerciasis (river blindness) in Nigeria and other West African countries. They therefore constitute serious public health and socio-economic problems in the areas that they occur. The study was undertaken to assess some physical and chemical factors affecting the distribution of *Simulium damnosum* complex in Oji river basin, Enugu state, Nigeria.

Study Design: Larval prospection was carried out in eleven riverine breeding sites in Oji river basin and physical-chemical parameters these breeding sites were evaluated.

Place and Duration of Study: A one year study was carried out between December 2011 and November 2012 in four communities in Oji river Local Government Area, Enugu state.

Methodology: Physical and chemical parameters of the breeding sites such as water temperature, velocity, turbidity and pH were determined. Measurements were taken between 10:00 and 11:00 hours local time on each visit. The features of the sites were also assessed by visual observation and scored as either presence or absence of rocks, logs and trailing vegetation and presence or absence of human and animal activities.

Results: A total of two hundred and ninety-one (291) *S. damnosum* complex larvae were collected. Of the physico-chemical characteristics measured, water velocity and turbidity ($P < 0.05$) were the only parameters showing significance with the distribution of *S. damnosum* complex larvae at the breeding sites.

Conclusion: This study provides information on prevailing physico-chemical characteristics of breeding habitats of *S. damnosum* s.l., which may have implications for vector distribution and disease transmission. This knowledge is crucial for accurate planning of onchocerciasis elimination programs.

Keywords: *Simulium damnosum* complex, Onchocerciasis, physical, chemical, Nigeria

1. INTRODUCTION (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

Onchocerciasis, also known as river blindness, is a vector-borne disease caused by the filarial worm *Onchocerca volvulus*. The disease is endemic in Central and South America and the Yemen, but 99% occurs in sub-Saharan Africa, where it causes blindness and skin disease [1]. About 37 million people in tropical Africa and 140,000 others in Latin America are infected with *O. volvulus* [1,2], mostly those living in poor rural communities. Thirty-six (36) countries are affected, 30 of them are in Africa, south of the Sahara, in a wide zone that lies from Senegal to Ethiopia. The endemic area extends from south of the equator to Angola in the west and Tanzania in the east. Localized foci exist in Sudan and Yemen [3]. In many endemic countries including Nigeria, onchocerciasis constitutes a major public health and socioeconomic problem. It is a disabling disease that causes significant morbidity, psychosocial problems and reduced work, especially reduced agricultural productivity in populations affected by the disease [4]. The programs attempting to control onchocerciasis all currently rely primarily on community-wide treatment of the endemic populations with Ivermectin.

In the major *O. volvulus* endemic areas of West Africa, the vectors are blackflies of the *Simulium damnosum* Theobald species complex [1]. Four sibling species of *S. damnosum* s.l. were identified in Oji river area and they include *S. squamosum*, *S. yahense*, *S. damnosum* s.s and *S. sirbanum* [5]. Physical and chemical characteristics play a role in determining the breeding sites of *S. damnosum* s.l. [6-9]. The breeding distribution of *Simulium* vectors on a broad scale is clearly related to both geology and bioclimatic zonation of Nigeria [10]. *S. damnosum* s.l. is traditionally considered to be a species of fast flowing, broken 'white-water' in rapids of rivers, and medium-sized streams, especially in upland areas [11]. Heavy rainfall causes a temporary effect on the population due to flooding and dislodging of blackflies from attachment substrates. Moderate rainfall enables higher egg and larval population to reach maturity while swiftly running water is a primary factor which certifies a place fit for use as a breeding site [12]. The attraction for and choice of site for an ovipositing female blackfly is affected by a number of other interacting factors other than velocity of water. These include water temperature, conductivity, pH, turbidity and light intensity [12].

The current strategy for controlling onchocerciasis in the mesoendemic Oji Local Government Area [13] is based on annual chemotherapeutic treatment of the communities with Ivermectin (Mectizan®), a microfilaricide, as there is no vector control. Oji River basin, which is the major water body in the area, supports intense breeding of blackflies. Following the recent shift from onchocerciasis control to onchocerciasis elimination by the end of 2015, an understanding of the prevailing physical and chemical characteristics of the breeding habitats of *S. damnosum* s.l. is imperative for understanding disease epidemiology, and for the rational design of disease elimination programmes. Therefore, the present work is aimed at assessing the physical and chemical characteristics of the breeding sites of *S. damnosum* s.l. in Oji river basin, which is important in describing the entomological profile of human onchocerciasis transmission, imperative for successful elimination of human onchocerciasis in the Oji river area.

2. MATERIAL AND METHODS

2.1 Study area

Oji River Local Government Area of Enugu state is a semiurban area located in the forest zone of southeastern Nigeria. The area has a landmass of approximately 403km² and a population of 126,587 at the 2006 census. The geographical coordinates are 06°16'N and 07°16'E and it has an altitude of 140m. Oji River Local Government Area is made up of 6 communities namely Oji urban (Oji town), Achi, Ugwuoba, Inyi, Awlaw and Akpugo-eze.

Oji has two seasons: wet (rainy) and dry seasons. The wet season lasts approximately from April till October and is characterized by high humidity and strong rainfalls. The average annual rainfall is around 2000 mm. Heavy rainfall occurs between June and July, with an average of 3600 mm in July. The dry season is usually hotter than the rainy period and lasts from November till March. The lowest rainfall of about 1600 mm normally occurs in February. This period is also characterized by dry and dusty harmattan winds in January and February. The mean temperature range is usually between 26.8°C to 32.5°C over the year and an average relative humidity of 84%.

The major water body in the area is the perennial, well-aerated and fast-flowing Oji River, a tributary of the Anambra River, which itself is a major tributary of the lower Niger River. Many rivers and streams traversing the Udi Hill escarpments flow into Oji River. Luxuriant growth of vegetation along the river banks and several geological formations in the riverbeds create rapids, providing suitable breeding sites for the *Simulium* flies in the area. The water is usually turbid with increased turbidity during the rainy season due to allochthonous inputs. The river is dammed at the Oji town to serve the Oji River Power Station and this also increased the speed of flow of the river.

2.2 Prospection for *Simulium damnosum* complex larvae

Simulium larvae were collected from eleven (11) riverine breeding sites. Collections were carried out from December 2011 to November 2012. Samples were randomly collected from multiple substrates and fixed in freshly prepared Carnoy's solution [95% ethanol and glacial acetic acid mixture of 3:1 (v/v)] in universal sample bottles. The larvae of *S. damnosum* s.l. were distinguished from other Simuliids by the presence of dorsal tubercles and scales on the body, as described by [6].

Physical and chemical parameters of the prospected sites were determined (five positive sites and five negative sites for *S. damnosum* complex larvae). The five negative sites were chosen randomly from the six negative sites encountered. Measurements were taken between 10:00 and 11:00 hours local time on each visit to maintain a constant time. The features of the sites were assessed by visual observation and scored as either presence or absence of rocks, logs and trailing vegetation and presence or absence of human and animal activities like abattoir wastes, excreta, refuse, washing of clothes and cassava. The parameters determined were water temperature, water velocity, water pH and water turbidity.

Water temperature was measured using a Hanna® digital thermometer as near as possible to the place where larvae were found. The thermometer was submerged in the water for two minutes before readings were taken.

Turbidity was measured as an average of two readings of a Secchi-disc. The Secchi-disc was lowered into the water until it disappeared from sight, and the depth recorded [14].

Water velocity was estimated using the float method [15]. A cork was thrown into the water and the time taken to cover two meters (one meter before and after an identified substrate) was determined using a stop watch. This was repeated three times and the average distance in meter per second was determined.

The Hanna® portable battery-powered pH meter was used to measure pH. It was immersed near as possible to the place where larvae were found for two minutes before readings were taken.

2.3 Data Analysis

Data analysis was performed on GraphPad Prism version 6. The data on physico-chemical characteristics were analyzed by t-test. Statistical significance was set at $P < 0.05$.

3. RESULTS

The 11 riverine breeding sites sampled in the study area include Oji Mile 2, Oji Wonderful and Oji Power Station in Oji Urban community, Oji Ehuhe, Oji Adu, Oji Enuguakwu and Oji Ahani in Achi community, Oji Alum, Mmamu, Achi iyi in Inyi community and Ozom in Ugwuoba community. Of these 11 sites, only five (5) sites were found positive for *S. damnosum* s.l. larvae. The five (5) sites are Oji Mile 2, Oji Ehuhe, Oji Adu, Oji Alum and Mmamu. A total of two hundred and ninety-one (291) *S. damnosum* complex larvae were successfully scored and identified during the twelve-month study period. The relative abundance of larvae identified from the five positive sites mentioned above is 78 (26.80%), 57 (19.59%), 50 (17.18%), 65 (22.34%) and 41 (14.09%) respectively. The difference in abundance of *S. damnosum* complex in the five sites was not statistically significant ($P = 0.2551$).

The topographic features of the prospected sites showed that the sites that were positive for larvae of *S. damnosum* complex had densely shaded vegetation, dense rocky substrata and submerged plants. The negative sites exhibited a high level of human and animal activities including abattoir wastes, sparse rocky substrata and submerged plants.

Table 1 and Figure 1 show the seasonal and monthly *S. damnosum* complex larval collections. *S. damnosum* complex larvae were present during both wet and dry seasons and in all the months covered in the present study. However, majority of the *S. damnosum* complex larvae were collected during the dry season (51.89%) compared to 48.11% in the wet season. Comparison of the dry and wet season collection shows that there were no significant differences in the distribution by season ($P = 0.7730$). *S. damnosum* complex larvae were most abundant in the month of December followed by November and May, which had equal larval abundance. The lowest number of larvae was collected in the month of July. The monthly abundance of *S. damnosum* complex larvae at the different sites was significantly different ($P = 0.0249$).

Table 2 shows the physical and chemical properties of the prospected sites in Oji River Local Government Area. The positive sites recorded higher mean values for all the parameters determined than the negative sites except pH whose values was higher in the negative sites. However, only water velocity ($P = 0.0013$) and turbidity ($P = 0.0152$) showed significant relationship with the distribution of the breeding sites of *S. damnosum* complex among the parameters determined.

145 4. DISCUSSION

146 There was a high number of breeding sites that were with *S. damnosum* complex larvae, which is an
 147 indication of intense breeding of *S. damnosum* complex in the area as well as preponderance of their
 148 breeding sites. The absence of *S. damnosum* complex in some of the likely habitats may be as a
 149 result of differences in the microhabitat conditions of these individual sites. For instance, during the
 150 study it was observed that at some of these negative sites like Oji Wonderful and Ozom, there was
 151 pollution of the water bodies with domestic wastes, and human and animal activities like defecation
 152 and washing of cassava and clothes were carried out in the water bodies. In these polluted waters,
 153 there may be an increase in ammonia concentration and a decline in dissolved oxygen, thereby
 154 reducing productivity and biodiversity. Also, at some of the negative sites, the fast flowing parts had
 155 very sparse substrates available for the adult female blackfly to oviposit. Moreover, some of the
 156 available breeding substrates were covered with algae which prevented attachment of eggs, and
 157 subsequently the larvae and pupal stages and this observation is in agreement with previous studies
 158 [16,17].

159
 160 There were seasonal variations in the abundance and distribution of *S. damnosum* complex
 161 cytospecies. About fifty-two percent (52%) of the cytospecies were collected during the dry season.
 162 This concurred with previous results [8,18] where higher numbers of *S. damnosum* complex were
 163 recorded in the dry season. The resultant high density of larvae during the dry season may be due to
 164 stability in the water level and rapid increase of breeding sites, low density of predators and the
 165 establishment of those species with high reproductive potential. In the present study, the month of
 166 December recorded the highest number of *S. damnosum* complex cytospecies while July when heavy
 167 rainfall occurs had the least number of larvae. It should be noted that apart from the seasonal pattern
 168 of rainfall, there was release of water from Lagdo dam in Cameroon into Nigeria between August and
 169 October, 2012. This resulted in downstream flooding and this is another factor that may have led to
 170 the reduced number of larvae collected during the wet season. The flood may have covered the
 171 available attachment substrates and also dislodged the aquatic stages of the flies from these
 172 substrates. Oviposition becomes affected due to the limited substrates that are will become available
 173 for the deposition of eggs and attachment of hatching out larvae.

174
 175 The breeding of *S. damnosum* complex is influenced by physical and chemical characteristics existing
 176 in a particular breeding site as previously suggested [8, 19-21]. This observation agrees with the
 177 findings of the present study. The positive sites which supported the breeding of *S. damnosum*
 178 complex recorded higher mean values for all the parameters determined than the negative sites
 179 except pH whose values were higher in the negative sites. The values recorded in this study were
 180 within the ranges recorded elsewhere in Nigeria [7, 9-10, 18, 22-25]. However, only water velocity and
 181 turbidity showed significant relationship with the distribution of the breeding sites of *S. damnosum*
 182 complex among the parameters determined. It is believed that water velocity is one of the most
 183 important ecological factors influencing the distribution and abundance of blackfly larvae and pupae
 184 [26]. This is because water current with its attendant increase in nutritive status of the site, level of
 185 oxygenation and presence of adequate supports brings larval food, supply oxygen to larvae and
 186 pupae and help larvae to migrate to more suitable positions in streams [27]. High turbidity of water
 187 reduces light penetration into the water mess, which will in effect lead to reduction in photosynthetic
 188 activities [28]. Turbidity is directly associated with rainfall and pollution in any freshwater environment,
 189 during which organic particles (dissolved and suspended solids) washed from the soils are carried in
 190 water bodies. Therefore, a highly turbid water body will adversely affect the distribution of *S.*
 191 *damnusum* complex in the breeding site.

192 5. CONCLUSION

193 This study provides information on prevailing physico-chemical characteristics that may determine
 194 survival as well as spatial distribution of *S. damnosum* s.l., in their breeding sites. This may have
 195 implications for vector distribution and human onchocerciasis disease transmission. This knowledge is
 196 crucial for accurate planning of onchocerciasis elimination programs in the study area.

197 REFERENCES

198
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ABBREVIATIONS

WHO: World Health Organization
APOC: African Programme for Onchocerciasis Control
s.l.: sensu lato
s.s: sensu strict

Table 1: Seasonal/monthly *S. damnosum* complex larval collections in the positive sites in Oji River Local Government Area

SITE	DRY SEASON					DRY SEASON TOTAL	WET SEASON							WET SEASON TOTAL
						n (%)								n (%)
	NO V	DE C	JA N	FE B	MA R		AP R	MA Y	JU N	JU L	AU G	SE P	OC T	
OM	12	14	5	4	9	44 (29.14)	9	10	7	1	2	3	2	34 (24.29)
OE	7	8	3	2	4	24 (15.89)	9	10	6	1	2	3	2	33 (23.57)
OA	7	8	2	3	5	25 (16.56)	6	8	5	2	0	2	2	25 (17.86)
OAI	10	12	4	3	7	36 (23.84)	7	9	6	1	2	2	2	29 (20.71)
MM	6	7	3	2	4	22 (14.57)	5	5	3	0	1	1	4	19 (13.57)
TOTAL	42	49	17	14	29	151 (51.89)	36	42	27	5	7	11	12	140 (48.11)

Key- OM: Oji Mile 2, OE: Oji Ehuhe, OA: Oji Adu, OAI: Oji Alum, MM: Mmamu

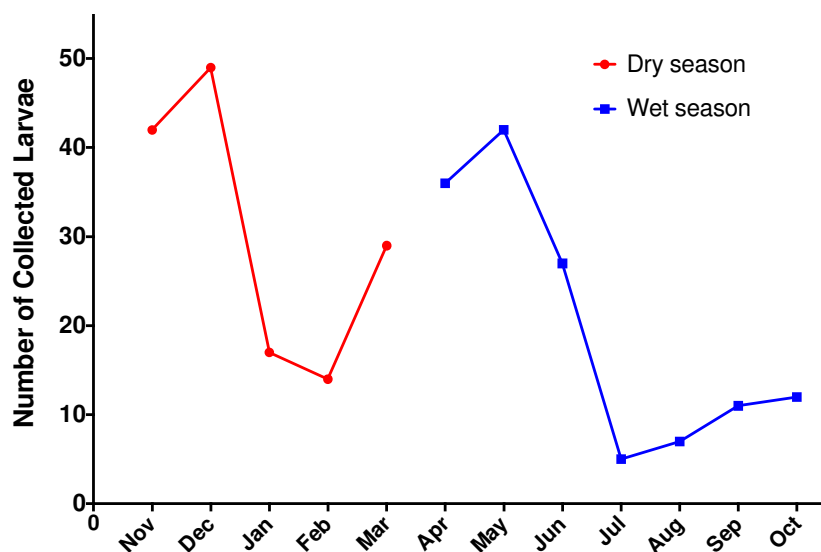


Figure 1: Monthly/Seasonal distribution of *S. damnosum* complex larvae

Table 2: Physical and Chemical Properties of the Prospected Sites

PARAMETER	MEAN VALUE±SE IN THE POSITIVE SITES (n=5)	MEAN VALUE±SE IN THE NEGATIVE SITES (n=5)
Water temperature (°C)	25.80±0.29	25.70±0.10
Water velocity (m/s)	1.60±0.11	0.70±0.15
pH	7.01±0.02	7.27±0.30
Turbidity (cm)	58.50±5.20	39.80±3.14