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Influence of Agro-chemical Inputs on Suitability of Physicochemical Conditions of Rice-Fields for Mosquito Breeding in Minna, Nigeria

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Abstract The influence of chemicals used in rice farming in Minna, on physicochemical properties of rice-field mosquito larval habitats was investigated during the rainy season of 2013. Standard water quality analyses techniques were followed in determining the concentrations of the different physicochemical parameters. The results showed that Temperature, Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) did not vary significantly among the types of rice fields (range = 30.00±0.00 to 30.50±0.11°C, 6.00±0.00 to 7.00±1.41 mg/l, and 4.00±0.00 to 4.50±2.12 mg/l, respectively). Turbidity and Nitrates were significantly ($p<0.05$) highest in rice fields without chemical inputs (site A), with values ranging from 0.27±0.21 to 0.24±0.18 NTU and 9.92±1.94 to 7.72±2.23 mg/l, respectively. However, these two parameters were not significantly different ($p>0.05$) between site B (rice field with chemical fertilizer only) and site C (rice field with chemical fertilizer and herbicide). Levels of Alkalinity, Hardness, Sodium and Conductivity were highest in site B and least in Site C, with values ranging from 31.00±15.56 to 132.00±19.79 mg/l, 32.00±14.14 to 81.00±41.01 mg/l, 38.15±2.75 to 51.70±1.41 mg/l and 194.00±43.84 to 508.50±44.5 µs/cm, respectively. While the concentration of Potassium was significantly ($p<0.05$) lowest in site A (10.40±0.14 mg/l), the concentration of Chloride was significantly lowest in site C (23.41±15.03 mg/l) and highest in site A (31.45±4.03 mg/l). Significant positive and negative correlations between some of the parameters were also recorded. These results suggest differential suitability of rice field physicochemical condition for mosquito breeding in Minna and, thus, should provide baseline guide for mosquito vector control in relation to sustainable rice farming in the area.

Keywords Rice fields; Agricultural chemical inputs; Mosquito larval habitat

Background

Nigeria is the most populous country in Africa, with a population of over 130 million people. Its domestic economy is dominated by agriculture, which accounts for about 40% of the Gross Domestic Products (GDP) and two-third of the labour force (Akande, 2000). Generally, cereal crops including sorghum, maize, millet, rice and wheat, etc. are considered staple and of prime importance in ensuring food security and major source of income for households in Nigeria and of these cereals crops, rice is considered the most acceptable, resulting in about 10% increase in annual production, dictated by consumer preference. The Nigerian Government spends as much as $300 million on rice importation annually (Akande, 2000).

Rice production and consumption in Nigeria cut across cultural, religious, ethinic or geographical boundaries. It is available in Five Star Hotels in the big cities and towns as well as in the ‘most local’ of eating places the remotest villages throughout the country. It is highly priced and widely accepted for festivities (Samson and Kadiri, 2007). Niger state is one of the major rice producing states in Nigeria (Saidu, 2008). The state has the highest average yield (on average 3 tons (t) of paddy) from a relatively limited area (on average less than two half) (Saidu, 2008).

Though, the use of agro-chemicals such as herbicides, insecticides and fertilizers, especially in rice farming is known to increase yield per unit area and time (Renato et al., 2011), such activities have widely resulted in the pollution of aquatic ecosystem, with particular negative effects on water quality. Moreby and Southway (1999), reported loss of diversity resulting from the de-structuring of physico-chemical conditions and alteration of natural dynamics of biological communities in aquatic ecosystems. Rice agro-ecosystems provide ideal breeding habitats for mosquito species. For example, rice irrigation farming is associated with the production of vectors that transmit pathogens to humans, including those responsible for malaria (Muturi et al., 2006).

Large scale environmental modification concomitant with processes such as forest clearing, irrigation development, human settlement and rice cultivation, inevitably result in changes in surface water quality and affect the survival of mosquito species breeding in surface water habitats (Yusuf and Olayemi, 2015). The physicochemical factors in Minna that influence oviposition, survival and spatio-temporal distribution of mosquito species in rice fields, include salts, dissolve organic and inorganic matter, degree of eutrophication, turbidity, presence of suspended mud, vegetation, temperature, light or shade and hydrogen ion concentration, which also may be affected by agrochemical inputs used in rice farming (Yusuf and Olayemi, 2015).

According to Lacey and Lacey (1990), Rice cultivation has traditionally been associated with vector-borne diseases, especially malaria and Japanese encephalitis. The mosquito vectors of these diseases lay eggs in standing water and the larvae need about 7-10 days in an aquatic environment to complete development to adults. The intermittent drying of rice fields was, therefore, tested for its mosquito control potential as far back as the early twentieth century (Takken et al., 1990). With the introduction of DDT after World War II, water management and other environmental measures to control mosquitoes were neglected. It is only since the 1980s, after the failure of the DDT-based eradication campaigns of malaria that environmental control measures are receiving renewed attention (Van der et al., 2001).

Olayemi et al. (2014) have documented the presence of high densities and diversity of vector mosquito species in Minna, the capital city of Niger state, and reported that drainages and rice fields were the most productive mosquito larval habitats in the city. Rice is widely grown in Minna, and is one of the most suitable habitats for mosquito larva productivity (Olayemi et al., 2014). The impacts of agrochemical inputs on the productivity of rice field mosquito larval habitats in Nigeria, generally, and Niger state, in particular, have not been well investigated, thus making sustainable cost effective rice production a problem in the country.

1 Materials and Methods

1.1 Study area

The study was carried out in Minna, the capital of Niger State, Nigeria, located within longitude 6^0 33’E and latitude 9^0 37’N, on a land area of 88 km^2 and having a population of about 1.2 million inhabitants. Minna has a typical tropical climate with mean annual temperature of 30.2°C, relative humidity of 61% and rainfall of 1334 mm. The climate in the area has two distinct seasons: rainy season (April-October) and a dry season (November-March), completely devoid of rains. Its vegetation is typically grass-dominated savannah with scattered short trees (Olayemi et al., 2009). Basically, four types of wetland rice ecosystems are present in Minna, which include irrigated, rain-fed low upland and wetland rice ecosystems, with the irrigated rice environment been the dominant (Akintayo, 2011). Farming is a major pre-occupation of the inhabitants of Minna and environs, with the area particularly famous for rice production; being a staple food in the area.

1.2 Selection of rice field mosquito larval habitats

Questionnaire were administered to farmers to determine the types and combinations of agricultural chemical inputs, i.e., chemical fertilizer, herbicides or both, commonly used in rice farming in Minna. Thereafter, guided by the results of the questionnaire test, three types of rice farming chemical inputs sites in two rice field categories, rain-fed lowland and irrigated ecosystems were selected each with three replicates. The three types of sites were named: type A (rice fields with no chemical input; serving as Control), type B (rice fields with only fertilizer application), type C (rice fields with both fertilizer and herbicide application). The sites were widely located at Fadukpe, Tunga and Chanchaga area of the metropolis (Figure 1).

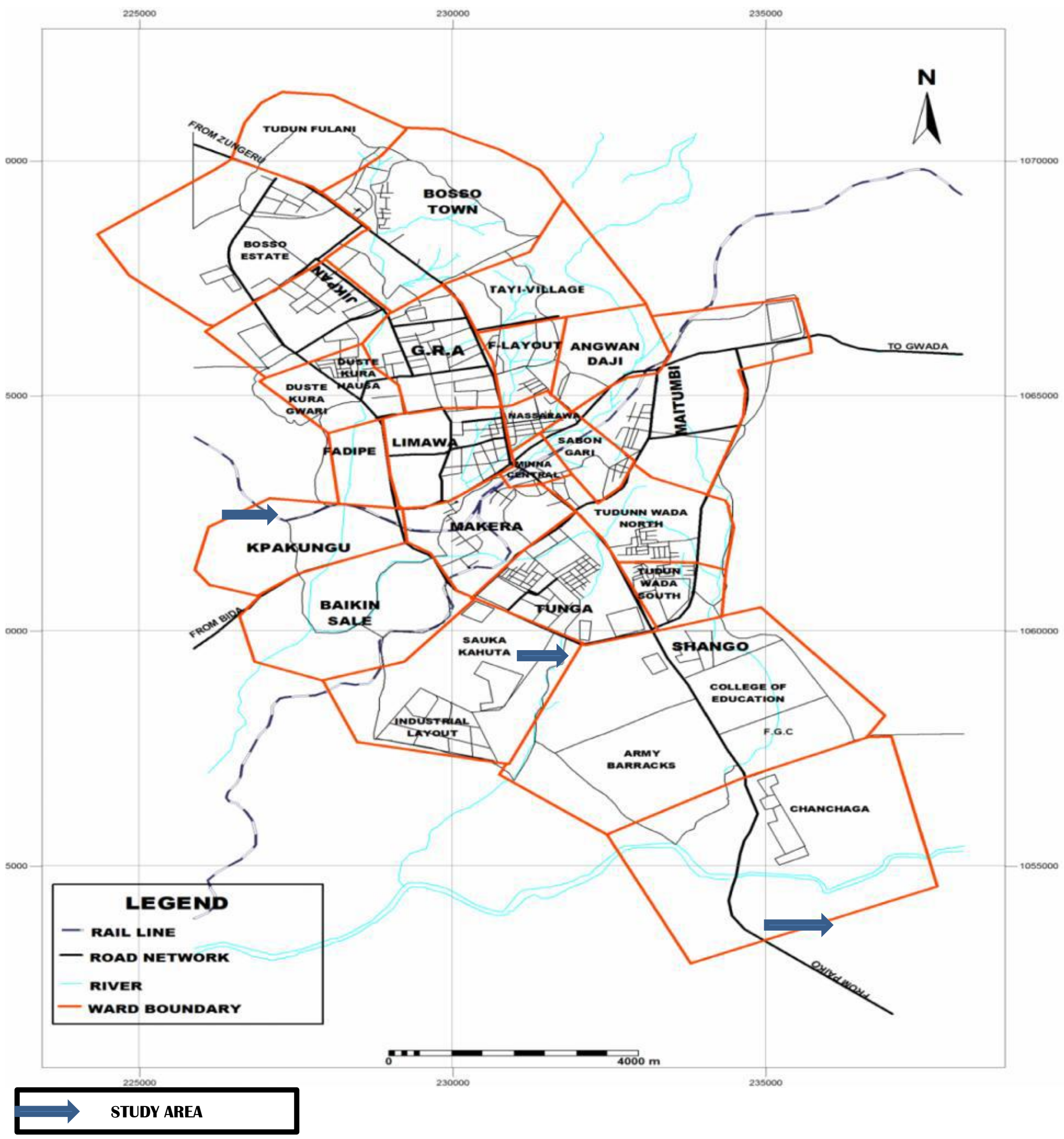

Figure 1 Minna street guide map showing the study area (Source: Urban and Regional Planning Department, FUT, Minna, 2012)

1.3 Collection and analyses of water samples for physicochemical properties of rice fields

Water samples were collected from each selected rice field between the hours of 08:00 and 09:00 am, at a depth of 5 cm, on each sampling day. 500 ml of water sample was collected per rice field using sample bottles of 500 ml capacity. Temperature (^oC) and Hydrogen ion concentration (pH) were measured *in situ* at the sites, using mercury thermometer and pH meter, respectively. The other parameters namely Turbidity, Conductivity, Potassium, Sodium, Chloride, Nitrate, Phosphate, Alkalinity, Hardness, and Dissolved Oxygen (DO) were determined in the laboratory within 2-3 hours of collection, while Biochemical Oxygen Demand (BOD) was determined on day five after collection, using the standard methods described by American Public Health Association (1992).

1.4 Statistical analysis

Data collected from all the sites and sampling periods were processed as mean ±S.D, using EXCEL programme. Mean values of the variables per treatment were compared for significance of statistical differences using appropriate tools of ANOVA and Duncan Multiple Range Test at P = 0.05 level of significance.

2 Results

2.1 Physicochemical condition of the rice field mosquito larval habitats

The indices of physicochemical conditions of the rice field mosquito larval habitats in Minna are presented in Table 1. Temperature, Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) did not varies significantly

(P>0.05) among the rice fields subjected to different agricultural chemical inputs. The mean temperatures however, ranged from 30.00±0.00 to 30.50±0.00°C, while DO and BOD were 6.00±0.00 to 7.00±1.41 mg/l and 4.00±0.00 to 4.50±0.71 mg/l, respectively. On the other hand, Turbidity, Nitrate and Chloride were significantly (P<0.05) higher in site A (rice-fields without agrochemical inputs), where they ranged as follows: 0.27±0.24 to 0.24±0.18 NTU, 9.92±1.94 to 7.72±2.23 mg/l and 31.45±15.00 to 23.41±15.00 mg/l, respectively. The distribution of the concentrations of chloride among the sites followed the same trend, been significantly highest in site A (mean = 31.45±03 mg/l). Alkalinity, Hardness, Sodium and Conductivity were highest in site B (rice field with only chemical fertilizer application) (means = 132.00±19.79 mg/l, 81.00±41.01 mg/l, 51.70±1.41 mg/l and 508.58±44.54 μS/cm, respectively) and least in site C (rice field with both fertilizer and herbicide) (means =31.00±15.56 mg/l, 32.00±14.14 mg/l, 38.15±2.75 mg/l and 194.00±43.84 μS/cm, respectively). The concentration of Potassium was significantly lowest in site A (10.40+0.14 mg/l) and did not significantly differ between sites B and C (14.40+0.14 mg/l and 13.40+3.11 mg/l, respectively).

Table 1 Variation in physicochemical properties of rice-field mosquito larval habitats subjected to various agricultural chemical inputs in Minna, Nigeria

PHYSICO-CHEMICAL PARAMETERS	Site A	Site B	Site C
Temperature (°C)	30.50 ± 0.71^{a}	30.00 ± 0.00^{a}	30.00 ± 1.41^{a}
pH	6.57 ± 0.51^{a}	7.17 ± 1.48^{b}	6.16 ± 0.11^{a}
Turbidity (NTU)	0.27 ± 0.35^{b}	0.24 ± 0.28^{a}	0.24 ± 0.21^{a}
Conductivity (μS/cm)	344.50 ± 61.51^{b}	508.50 ± 44.54^{c}	194.00 ± 43.84^{a}
Alkalinity (mg/l)	75.00 ± 21.21^{b}	132.00 ± 19.79^{c}	31.00 ± 15.56^{a}
Hardness (mg/l)	62.00 ± 19.79^{b}	81.00 ± 41.01^{c}	32.00 ± 14.14^{a}
Potassium (mg/l)	10.40 ± 0.14^{a}	14.90 ± 2.12^{b}	13.40 ± 3.11^{b}
Sodium (mg/l)	47.75 ± 2.33^{b}	51.70 ± 1.41^{c}	38.15 ± 2.75^{a}
Phosphate (mg/l)	5.58 ± 2.69^{b}	2.71 ± 1.77^{a}	9.98 ± 1.69^{c}
Nitrate (mg/l)	9.92 ± 1.94^{b}	7.93 ± 3.18^{a}	7.72 ± 2.23^{a}
Chloride (mg/l)	31.45 ± 4.03^{c}	27.47 ± 0.49^{b}	23.41 ± 15.03^{a}
D.O (mg/l)	7.00 ± 1.41^{a}	6.00 ± 0.00^{a}	6.00 ± 2.83^{a}
B.O.D (mg/l)	4.50 ± 0.71^{a}	4.00 ± 0.00^{a}	4.50 ± 2.12^{a}

Note: * Mean values followed by the same superscript alphabets in a row are not significantly different at P = 0.05; Site A: rice-field without agrochemical application; Site B: rice field with only chemical fertilizer application and Site C: rice-field with both fertilizer and herbicide application; * Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD)

2.2 Relationships within the physicochemical conditions

Table 2 shows the relationships that exist between the physicochemical parameters, in which some were significantly correlated while others were not. Significant positive correlation among the physicochemical parameters include those between Chloride and Temperature (r=0.95), Conductivity and pH (r=0.96), Alkalinity and pH (r=0.93), Sodium and pH (r=0.89), Alkalinity and Conductivity (r=0.96), Sodium and Alkalinity (r=0.88), DO and Nitrates (r=0.92), DO and Chloride (r=0.76), DO and BOD (r=0.94). On the other hand significant negative correlation also exist among the following parameters Phosphate and pH (r= -0.92), Phosphate and Conductivity (r= -0.97), Phosphate and Alkalinity (r= -0.97), phosphate and Sodium (r= -0.91). Potassium distinctly showed a negative correlation between sodium, Phosphate, Chloride, DO and BOD.

3 Discussions

The results of this study showed that water temperature, Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were not significantly affected by agrochemical inputs in the rice-field larval habitats. The temperatures recorded in this study were considerably lower than the 40.00°C maximum limit for the thriving of aquatic organisms by Federal Environmental Protection Agency (FEPA, 1990). This may be due to the fact that water temperature is generally dictated by atmospheric temperature, as influenced by the amount of absorbed solar radiation (Kemker, 2014). The conductive water temperature in Minna rice-fields may mean that such habitats are active vector-mosquito production sites, with its attendant public health implications in the area. According to Kawo et al. (2004) low water temperatures eliminate thermal pollution in aquatic habitats and promote the thriving of invertebrates.

Table 2 Cross correlation between the physicochemical parameters of rice field's mosquito larval habitats subjected to various agricultural chemical inputs in Minna, Nigeria

Physico-chemical Parameters	Temperature	pH	Turbidity	Conductivity	Alkalinity	Hardness	K	Na	Phosphate	Nitrate	Chloride	D.O	B.O.D
Temperature	1.00												
pH	0.23	1.00											
Turbidity	**0.73***	0.38	1.00										
Conductivity	0.18	**0.96***	0.30	1.00									
Alkalinity	-0.06	**0.93***	0.20	**0.96***	1.00								
Hardness	0.32	0.69	0.07	0.69	0.59	1.00							
Potassium	-0.70	0.19	**-0.74***	0.14	0.30	0.21	1.00						
Sodium	0.31	**0.89***	0.37	**0.96***	**0.88***	**0.77***	-0.04	1.00					
Phosphate	0.02	-0.92	-0.07	**-0.97***	**-0.97***	**-0.70***	-0.34	**-0.91***	1.00				
Nitrate	0.50	-0.20	0.21	0.01	-0.20	0.12	**-0.71***	0.22	0.08	1.00			
Chloride	**0.95***	0.35	0.69	0.38	0.12	0.42	**-0.70***	0.51	-0.18	0.64	1.00		
D.O	0.65	-0.14	0.23	0.03	-0.23	0.08	-0.68	0.17	0.09	**0.92***	**0.76***	1.00	
B.O.D	0.69	-0.25	0.19	-0.15	-0.41	-0.04	-0.62	-0.05	0.27	**0.76***	**0.72***	**0.94***	1.00

Note: * = significantly correlate

The DO recorded in the rice-fields in this study (range = 6.00 – 7.00 mg/l) were higher than those (i.e., 4.42 – 4.70 mg/l) reported in a reservoir elsewhere in the state (Ibrahim et al., 2009). The higher DO in this study may be due to high density of phytoplankton that characterize rice-field ecosystem generally (Alshami et al., 2014). Phytoplanktons are the principal producers of Oxygen, as by-product of photosynthesis, in aquatic habitats (Alshami et al., 2014).

The BOD recorded in this study is lower than reported by Sangpal et al. (2011) from India, who attributed the high BOD in the aquatic habitat to excessive discharge of sediment and sewage into the water body. This may mean that the rice-fields in Minna are not organically or chemically polluted.

The concentrations of turbidity, Nitrate and Chloride were significantly higher in rice-fields where there were no applications of agrochemicals (i.e., Site A). The higher turbidity in this site may be due to higher run-off discharge from the surrounding land area. The magnitude of run-off into aquatic habitats is often influenced by anthropogenic activities in the surrounding area (Leroy et al., 2002), and this may vary considerably in different rice-field mosquito larval habitats. The higher Nitrate content of site A may also be due to higher deposition of sewage, the principal source of Nitrate in aquatic ecosystems (Mateo-Sagasta and Jacob, 2012). High Nitrate content may result in algal bloom in aquatic habitats (Glendon et al., 1999) and, hence, increased mosquito productivity, as the larvae will have access to abundant food supply (Alan et al., 2003).

The concentrations of Alkalinity, Hardness, Sodium and Conductivity were significantly higher in rice-fields with fertilizer application. This may be an indication of physico-chemical parameters singly affected by chemical fertilizers in aquatic habitats. Alkalinity and Conductivity, for example, are known to influence the survival and productivity of aquatic invertebrates (William, 2000). Therefore, this may mean that rice-fields subjected to only chemical fertilizer application in Minna produce mosquitoes at differential rates from the other counterpart habitats subjected to other kind of agrochemical practices. The level of Alkalinity, water hardness and Chloride recorded in the rice-fields in this study fell within ranges optimum for the productivity of aquatic organisms including mosquitoes (Ramatake and Morghe, 1998; Idowu et al., 2004; Girgin et al., 2010). The concentration of Potassium was significantly higher in sites B and C, where there were applications of inorganic fertilizer. This should be expected, as Potassium is one of the three major components of inorganic fertilizers (i.e., NPK used) in the study area. However, this may mean that rice farmers in Minna wrongly use the NPK fertilizer for their crops instead of the Urea (Nitrogen-based) fertilizer, recommended for optimum rice productivity. This assertion is buttressed by the facts that Nitrate concentration was even higher in rice-fields where there was neither fertilizer nor herbicide application.

4 Conclusions

Agro-chemical input practices in rice farming in Minna though may enhance yield, significantly alter critical physic-chemical parameters that condition the development and thriving of mosquitoes in the larval habitats. The little or no significant effects of the agro-chemical on Temperature, Dissolved Oxygen and Biological Oxygen Demand may not promote mosquito production but this gain is effectively countered by the enhancement of Alkalinity, Sodium, Potassium and Conductivity which are critical in mosquito immature development. The strong correlations between vital physico-chemical parameters indicate that such factors act collectively or perhaps, in-synergy on mosquito development. This probable relationships between mosquito immature development and collegiate of physico-chemical parameters requires urgent elucidation. The findings of this study should provide baseline information for cost-effective management of mosquito productivity in rice wetlands in Minna and, by extension, in Nigeria as a whole.

Author's contributions

OIK and SIM designed the experiment; SIM and GY analysed the data; SIM, GAY and UMD wrote the draft manuscript; OIK, SIM and UAC contributed to writing of the main manuscript; All authors agree with manuscript results and conclusion; finally the articulated manuscript were read and reviewed together.

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