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The Presence of Microcystins in Aquatic Ecosystems in Northern Nigeria: Zaria as a Case Study

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Abstract: Evidence from research in most countries of the world has shown that Cyanobacteria blooms could exhibit acute and chronic toxicity to man and animals alike. Despite the availability of records from other countries of the world, there is no information on the occurrence of these toxins in Northern Nigeria. This study reports the findings of a survey for the occurrence of microcystins in aquatic ecosystems in Zaria Northern Nigeria, using Enzyme Linked Immunosorbent Assay (ELISA) based methods. Five out of the 15 aquatic systems surveyed had microcystins concentrations higher than the acceptable limits (1 μg L^{-1}) for portable drinking water. A total of eight Cyanobacteria species were recorded in this survey namely: *Anabaena* sp., *Microcystis* sp., *Spirulina* sp., *Merismopedium* sp., *Gloetrichia* sp., *Cylindrospermopsis* sp. and *Anabaenopsis* sp. In all the water bodies surveyed *Anabaena* sp. and *Microcystis* sp. had the highest frequency of occurrence and biomass (No. of cells per litre of water).

Key words: Microcystins, aquatic ecosystems, Zaria, Northern Nigeria

INTRODUCTION

Of all cyanotoxins, the cyclic peptides present the greatest concern to human health. This is because they have the potential for long-term exposure at comparatively low concentrations in drinking water supplies. The cyclic peptides (microcystins and nodularins) are specific liver poisons in mammals. Following acute exposure to high doses of these toxins, they cause death from liver haemorrhage or failure. They are also implicated for promoting the growth of liver tumours and other tumours, following chronic exposures to low doses. The short term effects in humans are gastrointestinal and hepatic illness. The outbreaks of these short term ailments have been consistently linked or correlated to natural or artificial breakdown of cyanobacterial blooms (Miller and Tisdale, 1931). Within human populations, for a variety of reasons, there are individuals who are at a greater risk of injury from cyanotoxins than the rest of the population. The most obvious example is in children because they drink a higher volume of water in proportion to their body weight than adults. Individuals with injured organs are very susceptible to cyanobacterial toxins; such as people with hepatitis and liver cirrhosis. Kidney dialysis patients for example are very vulnerable, if exposed to water containing microcystins during dialysis. This is because the nature of their treatment exposes them intravenously to a large volume of water (Jochimsen *et al*., 1998). While, acute toxicity is the most obvious problem in cyanobacterial poisoning, a long term risk may also be present. Experiments on animals have shown the possibility of chronic liver injury from continuous oral exposure to microcystins.

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In Africa, information on the occurrence and effects of Cyanobacteria blooms is scanty with the exception of South Africa; a few countries in the continent have research programmes in this field (Scott, 1991; Codd, 2000; Akin-Oriola and Lawton, 2006). There is paucity in the number of published works on Cyanobacteria diversity, blooms and toxins in Nigerian aquatic ecosystems. A few studies in Nigeria have reported the occurrence of algal blooms namely: Delimi River Jos (Kelly and Ali, 1993); Lagos Lagoon Lagos (Nwankwo, 1996); and Awba Reservoir Ibadan (Akin-Oriola, 2003). Only one study in Nigeria has dealt with the distribution of cyanotoxins in the Niger Delta region of the country (Odokuma and Isirima, 2007).

Secondary metabolites produced by Cyanobacteria have negative effects on the nervous, hepatic and dermatologic systems of wild and domestic animals. These result in poisoning and death of exposed animals (Lippy and Erb, 1976; Keleti *et al*., 1979; Carmichael and Falconner, 1993; Pouria *et al*., 1998; Kotut *et al*., 2005). There is a very high probability that humans and wildlife in Nigeria are perpetually exposed to chronic cyanotoxins poisoning from rivers, lakes and reservoirs. A major reason for this could be due to the fact that the traditional water treatment techniques used in Nigeria such as coagulation, sedimentation and filtration, have been shown to be partially effective in removing cyanotoxins; sometimes even resulting in lyses of cyanobacteria cells and further releasing of intracellular toxins (Chorus and Bartram, 1999; Akin-Oriola and Lawton, 2006; Hoeger *et al*., 2004, 2005).

There is no monitoring program or legislation in Nigeria to enhance proper monitoring, management and utilization of water resources in Nigeria with regards to cyanotoxins. In addition, the establishment of such a program is dependent on the availability of baseline information on the occurrence and distribution of cyanobacteria toxins in Nigeria. The success of such a program is further dependent on the availability of adequate facilities or resources for the detection and quantification of cyanotoxins. Existing water quality assessment and monitoring strategies that employ microbial and physicochemical criteria are inadequate for comprehensive assessment of water quality; especially in water bodies showing evidence of progressive eutrophication (Akin-Oriola *et al*., 2006). In addition, there is a serious water supply problem in Nigeria. The supply of water is highly unstable and insufficient to meet the requirement of the populace. As a result most Nigerians depend on water from ponds, lakes and rivers to meet their daily water requirement. There is therefore, the urgent need to generate data on the occurrence and concentration of cyanobacteria toxins in aquatic ecosystems in Nigeria. The availability of such data will help in the development of policies for monitoring and preventing of cyanobacteria blooms and their associated problems. The present study was carried out with the objective of screening aquatic ecosystems in Zaria, Northern-Nigeria for the presence of microcystins.

MATERIALS AND METHODS

Study Area

Zaria is located on a plateau at a height of about 2200 feet above sea level. It is centrally located in the Northern Guinea Savanna zone of Nigeria (11° 3´ N, 7° 42´ E). The climatic condition here is tropical continental with a distinct wet and dry season. The rainy season occurs from May to October and the dry season from November to April.

Kubanni Lake (ABU dam) is located within the premises of the Samaru campus of Ahmadu Bello University (11°08´N, 07° 43´E). The lake has two major tributaries: Kampagi River and Kubanni River. It is the major source of drinking water to the university community and its environs. It receives high levels of municipal waste from the surrounding University campus and Samaru Village (Bako *et al*., 2007). Makwaye Lake (11°12´N, 07°36´E) is located

North of Kubanni Lake. The lake is an unprotected natural lake ecosystem. Around the catchements of this lake, a lot of irrigation farming and animal grazing goes on unchecked. Bomo Lake is situated near Bomo village. It lies 6 km North-West of ABU Zaria (11°12´N, 07°38´E) and has evidence of human disturbance.

All these ponds were located between Samaru village and Danmagaji village, along Zaria-Kano Express way (11°08´N, 07°43´E), Zaria. The Aviation Quarry site pond (Located opposite the Nigerian Civil Aviation Training Center, Samaru, Zaria). Mairabo pond 1 and Mairabo pond 2 (lying side by side); Kabama pond; Danmika pond; and Jim Harrison pond (all 5 ponds are located within 2 to 3 km from each other). And lastly, the Living Faith Church Zaria (LFCZ) pond 1 (located in front of the Church); and LFCZ pond 2 (Located behind the Church) in Kwangila village.

River Kubanni flows in a North-South direction along a gully situated between Samaru village (11°10´N, 07°39´E) and the main campus of Ahmadu Bello University, Zaria. The gulley is about three kilometers (3 km) long. It receives effluents from surrounding built up areas in Samaru village such as houses, piggeries, laundries and student hostels (Danfodio and ICSA Halls of ABU). Some parts of this gully retain water throughout the year and have been suggested to cut through a perched water table.

River Galma (11°08´N, 07°45´E) is located in Sabon Gari. River Basawa (11°10´N, 07°40´E) flows behind Bassawa Army barracks. The factors that led to the selection of these rivers were: the establishment of industries; and farming activities that involve the use of fertilizers, pesticides and herbicides. These human activities result in the discharge into these rivers raw untreated sewage. Other human activities around and in these rivers include fishing and drinking by man and animals.

Sampling

The sampling period for this survey was from September 2008 to November 2008. Replicate samples for analysis were collected from three fixed sampling points per water body using an integrated hose pipe sampler (2.5 cm diameter and 5 m length), at about 30 cm depth and 1m away from shore (APHA, 1998). Three litter of water per sampling site was collected for microcystins analysis. The samples were stored in coolers on ice to maintain cooled conditions; to ensure that algae in the samples remained alive and at low metabolic states until they were properly processed in the laboratory. In the laboratory, samples for toxin analysis were stored at -20°C.

Cyanobacteria Analysis

Subsamples from already collected water using the Integrated Hosepipe sampler were concentrated in 100 mL glass jars. They were then fixed immediately with 0.1 mL of lugol solution to precipitate and preserve the Cyanobacteria cells (APHA, 1998). Samples for cyanobacteria analysis were taken to the laboratory for identification using the keys of Prescott (1978), APHA (1998), Bartram and Rees (2000). Abundance determination was done using the Drop Count Technique. Cyanobacteria analysis was carried out in the Postgraduate Laboratory of the Department Biological Sciences, Ahmadu Bello University, Zaria, Nigeria.

Analysis of Physicochemical Parameters

Analysis of physicochemical parameters and sample preservation were carried out in the Hydrobiology Laboratory of the Department Biological Sciences, Ahmadu Bello University, Zaria, Nigeria; Water temperature was determined using a Mercury thermometer. pH was determined with a Pye Unicam pH meter (model 292) at 25°C. Standardization of the pH meter was done using buffer solutions at pH 4.0, 7.0 and 9.0 before readings were taken. The

conductivity meter E.B.A/10 model was used to determine Electrical Conductivity (EC) (µmhos/cm). Dissolved Oxygen (DO) was obtained using the Modified Winkler Azide method (APHA, 1985). Total Dissolved Solids (TDS) was determined using. Spectrophotometric method and used to analyze samples for Phosphate-Phosphorus (PO_4-P) and Nitrate-Nitrogen (NO_3-N) concentrations with the aid of a HACH DR/2000 Direct Reading Spectrophotometer. PO_4-P and NO_3-N concentrations were read from a calibration curve (APHA, 1985).

Immunological Detection of Microcystins

Enzyme Linked Immunosorbent Assay (ELISA) was used to determine the presence and concentration of total microcystins in samples ; and this was done in the Algae Laboratory, National Research Institute for Chemical Technology, NARICT, Zaria, Nigeria.. This assay was based on the polyclonal anti body method of Chu *et al.* (1990) and adapted by An and Carmichael (1994). Antibody -coated tubes, standards and all reagents were supplied by Abraxis LLC (Cat.#520012, Warminster PA18974, USA). The level of sensitivity to microcystins using this kit was approximately 0.15 µg L^{-1}. The Abraxis ELISA kit is a competitive colometric assay and recognizes all microcystins variants. Microcystins were quantified using a Jenway spectrophotometer (Model 6400) at a wavelength of 450 nm in conjunction with a reference wavelength of 630 nm (Fischer *et al*., 2001; Hawkins *et al*., 2005).

Statistical Analysis

Analysis of variance was used to test for significant difference between means of analysed parameters. The Fisher´s Least Significant Difference (LSD) was used to separate significantly different means (Fisher, 1925).

RESULTS

Eight species of cyanobacteria were recorded in this study namely: *Anabaena* sp., *Microcystis* spp, *Spirulina* sp., *Marsoniella* sp., *Merismopedium* sp., *Anabaenopsis* sp., *Gloetrichia* sp. and *Cylindrospermopsis* sp. Quantitative analysis cyanobacteria showed that *Anabaena* sp. had the highest abundance (12×10^4cells L^{-1}) in all the aquatic ecosystems. It was closely followed by *Microcystis* sp. and *Spirulina* sp.; each species having an abundance of 9×10^4cell L^{-1}. The highest abundance of *Microcystis* sp. occurred in River Kubanni and LFCZ pond 1; while the highest abundance of *Spirulina* sp. occurred in LFCZ pond 2, Kabama pond, Mairabo pond 1 and Danmika pond. With respect to the frequency of occurrence, *Microcystis* sp. had the highest frequency of occurrence because it was recorded in all the water bodies surveyed except Kabama pond and Mairabo pond. Species of cyanobacteria like *Anabaenopsis* sp., *Gloetrichia* sp. and *Cylindropermopsis* sp. were only recorded in the lotic water bodies (Table 1).

Water temperature in all the water bodies ranged from 21.95+1.75°C to 27.70+0.20°C, throughout the study period. The highest value recorded for pH was 8.33+0.54 in the Aviation Quarry pond, while the least value was 6.52+0.05 in Mairabo pond 2. The lowest concentration of phosphate-phosphorus (0.13+0.03 mg L^{-1}) was noted in the aviation quarry pond. It was followed by Mairabo pond 2 with a PO_4-P concentration of 0.27+0.01 mg L^{-1}. The highest value for PO_4-P recorded (0.45+0.02 mg L^{-1}) was in Danmika pond. Nitrate nitrogen concentration ranged from 0.005+0.00 mg L^{-1} in the Aviation Quarry pond to 0.45+0.01 mg L^{-1} in River Basawa. It was observed that all the water bodies studied were rich in dissolved oxygen concentration. The lowest value of 15.08+2.89 mg L^{-1} was recorded in the aviation quarry pond and the highest value of 22.40+0.95 mg L^{-1} in the Ahmadu Bello University (ABU) Dam (Table 2).

Table 1: Diversity and abundance (× 10^4 cells L^{-1}) of cyanobacteria species recorded from the aquatic ecosystems surveyed

Sites	*Anabaena* sp.	*Microcystis* sp.	*Spirulina*	*Marssoniella*
Quarry pond	-	7,2	-	1,8
ABU Dam	1,8	0,9	1,8	7,2
Bomo lake	9	1,8	-	3,6
Makwaye lake	1,8	5,4	5,4	9
LFCZ pond 1	-	9	1,8	-
LFCZ pond 2	1,8	7,2	9	9
Jim harrison pond	9	3,6	-	1,8
Kabama pond	-	-	9	1,8
Labi pond	-	1,8	5,4	7,2
Mairabo pond	-	-	9	2,7
Danmika pond	0,9	7,2	9	1,8
Mairabo2 pond	2,7	1,8	7,2	1,8
River galma	7,5	3	-	-
River basawa	-	1,9	-	-
River kubanni	12	9	-	-

Sites	*Merismopedium*	*Gloetrichia*	*Cylindrospermopsis*	*Anabaenopsis*
Quarry pond	-	-	-	--
ABU Dam	-	-	-	-
Bomo lake	-	-	-	
Makwaye lake	-	-	-	-
LFCZ pond 1	-	-	-	-
LFCZ pond 2	-	-	-	-
Jim harrison pond	-	-	-	-
Kabama pond	-	-	-	-
Labi pond	-	-	-	-
Mairabo pond	-	-	-	-
Danmika pond	-	-	-	-
Mairabo2 pond	-	-	-	-
River galma	-	-	-	-
River basawa	-	2	-	3,5
River kubanni	6	-	6	-

Table 2: Physicochemical characteristics of the aquatic systems studied in Zaria, Northern-Nigeria

Sites	Temperature (°C)	pH	Electrical conductivity (µmhos cm^{-1})	Phosphate (mg L^{-1})
Aviation quarry pond	27.70 ± 0.20^{a}	8.33 ± 0.54^{a}	152.50 ± 32.70^{ab}	0.13 ± 0.03^{d}
ABU Dam	27.35 ± 0.05^{ab}	6.82 ± 0.08^{bc}	101.25 ± 12.55^{bc}	0.38 ± 0.04^{abc}
Bomo lake	27.35 ± 0.05^{ab}	6.76 ± 0.15^{bc}	40.50 ± 39.60^{d}	0.38 ± 0.04^{abc}
Makwaye lake	26.60 ± 0.60^{ab}	7.81 ± 1.05^{ab}	73.15 ± 1.45^{dc}	0.34 ± 0.03^{abc}
LFCZ pond 1	26.95 ± 0.45^{ab}	7.25 ± 0.01^{abc}	66.00 ± 2.00^{dc}	$0.38\pm$o.11^{abc}
LFCZ pond 2	26.95 ± 0.45^{ab}	7.25 ± 0.09^{abc}	55.00 ± 2.00^{dc}	0.28 ± 0.06^{cd}
Jim harrison pond	26.30 ± 0.20^{ab}	7.25 ± 0.01^{abc}	85.20 ± 0.00^{dc}	0.48 ± 0.03^{a}
Kabama pond	26.70 ± 0.20^{ab}	7.37 ± 0.01^{abc}	198.80 ± 0.40^{a}	0.36 ± 0.04^{abc}
Labi pond	26.40 ± 0.60^{ab}	7.26 ± 0.60^{ab}	68.50 ± 0.10^{cd}	0.29 ± 0.04^{bc}
Mairabo pond 1	26.80 ± 0.40^{ab}	6.84 ± 0.02^{bc}	108.00 ± 3.00^{bc}	0.43 ± 0.07^{abc}
Danmika pond	27.10 ± 0.70^{ab}	6.97 ± 0.01^{bc}	77.20 ± 0.30^{dc}	0.45 ± 0.02^{ab}
Mairabo pond 2	26.20 ± 0.40^{b}	6.52 ± 0.05^{c}	57.30 ± 0.30^{dc}	0.27 ± 0.01^{dc}
River galma	21.95 ± 1.75^{d}	7.09 ± 0.04^{bc}	126.65 ± 21.95^{bc}	0.39 ± 0.01^{abc}
River basawa	24.55 ± 1.15^{c}	7.21 ± 0.16^{b}	82.65 ± 6.35^{dc}	0.40 ± 0.06^{ab}
River kubanni	22.00 ± 1.50^{d}	7.38 ± 0.07^{abc}	144.25 ± 0.75^{ab}	0.28 ± 0.09^{cd}

Sites	Nitrate	Total dissolved solid	Dissolved oxygen
	----------(mg L^{-1})----------		
Aviation quarry pond	0.005 ± 0.000^{c}	76.25 ± 23.12^{b}	15.08 ± 2.89^{dc}
ABU dam	0.005 ± 0.002^{c}	36.63 ± 10.73^{cd}	22.40 ± 0.95^{a}
Bomo lake	0.007 ± 0.006^{c}	42.53 ± 2.48^{cd}	19.28 ± 2.48^{abcd}
Makwaye lake	0.031 ± 0.030^{bc}	36.58 ± 0.73^{cd}	19.28 ± 2.48^{abcd}
LFCZ pond 1	0.031 ± 0.011^{bc}	33.00 ± 2.00^{cd}	18.00 ± 1.50^{abcd}
LFCZ pond 2	0.100 ± 0.050^{ab}	28.50 ± 7.00^{d}	16.00 ± 1.95^{bcd}
Jim harrison pond	0.080 ± 0.010^{bc}	42.60 ± 0.02^{cd}	14.00 ± 0.03^{d}
Kabama pond	0.170 ± 0.020^{a}	99.40 ± 0.10^{a}	21.00 ± 0.50^{ab}
Labi pond	0.070 ± 0.000^{bc}	34.25 ± 0.03^{cd}	17.45 ± 0.02^{abcd}
Mairabo pond 1	0.080 ± 0.020^{bc}	54.00 ± 2.00^{c}	16.25 ± 0.05^{bcd}

Table 2: Continued

Sites	Nitrate	Total dissolved solid	Dissolved oxygen
	----------(µg L^{-1})----------		
Danmika pond	0.060±0.030^{bc}	38.60±0.60^{cd}	20.10±0.02^{abc}
Mairabo pond 2	0.040±0.030^{bc}	28.65±0.05d	19.50±0.01^{abcd}
River galma	0.420±0.01^{bc}	63.33±10.98^{c}	16.55±0.55^{bcd}
River basawa	0.450±0.01^{bc}	41.33±3.18^{cd}	15.80±0.60^{dc}
River kubanni	0.350±0.02^{bc}	72.13±0.38^{b}	16.40±2.40^{bcd}

Means with same letters along the columns are not significantly different at $p<0.05$

Table 3: Concentration of Microcystins in the Study water bodies in Zaria, Northern Nigeria

Sites	Optical density (nm)		Microcystin concentration (µg L^{-1})
	450	650	
Aviation quarry pond	1.826	0.066	BLD
ABU dam	1.378	0.249	2.40*
Bomo lake	1.210	0.325	3.80*
Makwaye lake	1.340	0.124	2.00*
LFCZI pond	1.970	0.142	BLD
$LFCZI_{2\ Pond}$	1.346	0.093	1.60*
Jim Harrison pond	1.472	0.128	1.40*
Kabama pond	1.795	0.090	BLD
Labi pond	2.140	0.116	BLD
Mairabo pond 1	1.796	0.169	0.15
Danmika pond	2.043	0.083	BLD
Mairabo pond 2	1.852	0.072	BLD
River galma	2.260	0.032	BLD
River basawa	2.044	0.018	BLD
River kubanni	1.904	0.026	BLD

*Microcystins concentrations above WHO acceptable limits (1 µg L^{-1}) for drinking water. BLD: Below level of detection

Immunological analysis of samples from the different aquatic systems revealed that 5 out of the 15 water bodies had microcystins concentrations above the acceptable limits of 1 µg L^{-1}(Table 3). The highest microcystins concentration of 3.80 µg L^{-1} was recorded in Bomo lake. ABU Dam had a concentration of microcystins (2.40 µg L^{-1}) closely following that Bomo Lake. The least detected concentration of microcystins (0.15 µg L^{-1}) was recorded in Mairabo pond. All the lotic water bodies surveyed had concentrations of microcystins below the level of detection by the kit used.

DISCUSSION

The observed differences between the different aquatic systems in their physicochemical parameters could be due to the differential rates of entrance of debris and other materials from their respective catchment areas. pH values were mostly maintained between a range (6.6-8.5) known to be optimum for most biological activities. Farming activities and sewage from homes constitute the major sources of raw untreated sewage to these aquatic ecosystems. The extent of these human activities in the different catchments of the respective water bodies could be implicated for the differences in the amount of nutrients (phosphate-phosphorus and nitrate-nitrogen) in these systems (Brenner *et al*., 1999). The areas surrounding these ponds vary in the extent of usage. This is because some parts are mostly used as farmlands, while the others for disposal of waste from automobile mechanic shops. The variation in TDS and EC in the different water bodies could also be attributed to differences in the rate of anthropogenic activities around the catchment and the extent of usage of water from the water bodies (Odhiumbo and Gichuki, 2000; Akin-Oriola, 2003).

The current survey showed that microcystins were present in 40% of the water bodies surveyed. This is consistent with results in other parts of the world. These reports state that sometimes up to 60% of samples analysed could be positive for microcystins (Chorus, 2001). The official WHO acceptable limit for daily intake of microcystins -LR is 1 μg L^{-1} (Chorus and Bartram, 1999). Some scientists have argued that this value is too high and suggested an upper limit of 0.1 μg L^{-1} (Annadotter *et al*., 2001). This study showed that 5 out of the 15 water bodies surveyed had toxicity levels above the maximum permissible level for portable drinking water. If one was to take the Annadotter *et al*. (2001) level of 0.1 μg L^{-1}, then conclusions will be made that all six water bodies with microcystins are not recommended for human use. A major cause for concern is the occurrence of high concentrations of microcystins in the Ahmadu Bello University (ABU) Dam. This dam provides drinking water for the university community and Samaru Village. There is the possibility that the university community has been drinking water from the dam with high concentrations of microcystins for a long time. Although, it is impossible to state at this point the temporal changes of the concentration of Microcystins in this lake because of the limitations of the current study. The same reason is applicable to the results from the other lakes with regards to microcystins concentrations. Nigeria as a whole has the problem of adequate supply of portable drinking water; as a result people resort to digging of boreholes and wells to get water. Communities that live around water bodies use water directly from them without treatment, to meet all their domestic needs. These activities include bathing, drinking and cooking. Evidence from research has shown that the boiling of water contaminated with microcystins does not result in denaturing of the cyclic peptides. They are known to be thermal stable at the boiling point of water (Chorus and Bartram, 1999). Furthermore, water from the ponds and the lakes are used in irrigation of agricultural crops. Research evidence has demonstrated that microcystins and other cyanobacteria toxins have the ability to bioaccumulate in living tissues of plants and animals. This is supported by the work of Codd *et al*. (1999) on Salad Lettuce. Their research showed that cells of *Microcystis aeruginosa* and microcystins were retained in the leaves of the plants. This is further supported by the findings of Pflugmacher *et al*. (2001, 2006) and Pflugmacher (2002) on different crop plants. The extent of this problem at present is not known in Nigeria as whole. There is no report on the presence, concentration and accumulation of these toxins in plant tissues. Therefore, making it impossible to estimate how much risk the people that depend on water from these water bodies are exposed to. Also, it is difficult to compare the results of this study with previous studies in Northern Nigeria; as this study is the first to report the presence of microcystins in aquatic systems.

In conclusion, the current survey has shown that the presence and concentrations of microcystins in some of the water bodies surveyed were higher than recommended levels. In areas where these water bodies serve as a major source of portable drinking water, more caution should be taken to prevent acute and chronic poisoning of humans, animals and plants. In addition, activities around the catchment areas of these aquatic bodies that increase the level of eutrophication should be discouraged. This will go a long way to prevent the regular occurrence of toxic cyanobacteria blooms. Therefore, it is recommended that the use of inorganic fertilizers by farmers around water bodies should be discouraged; human activities such as washing and bathing with soaps and detergents should be halted. There is the urgent need for more surveys to generate data in this area in Nigeria to help in understanding the extent of the situation. Furthermore, studies should be carried out to understand the temporal changes or dynamics of the occurrence and concentrations of microcystins (and other algal toxins) in aquatic systems in Nigeria as a whole.

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