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An Analysis of Knowledge, Attitudes and Practices of Communities in Lake Victoria, Kenya on Microcystin Toxicity

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Abstract

Exposure to microcystin poses a potential health hazard to humans and other living organisms. This results from eutrophication and warrants an investigation into the problem of microcystin toxicity in Lake Victoria. This study was conducted in Homa Bay, Kisumu, Siaya and Busia counties to understand the effects of microcystin toxicity among fisherfolk and lake riparian communities. Data collection involved 90 semi-structured questionnaires, 11 key informant interviews and seven focus group discussions. Water samples were also collected and analysed for algal toxins. Data were analysed using Stata version 13 (Stata Corp, College Station, Texas, USA) and SPSS version 18.0. Majority (73.3%) of the fisherfolk were aware of microcystin toxicity in the lake with no significant difference in the awareness of microcystin toxicity between men and women ($\chi^2 = 1.1$, df = 1, $p = 0.293$). Most of the respondents relied on lake (48.9%) and tap water (47.8%) with paltry sourcing water from borehole (16.8%) and rain (7.8%). There was no association between level of education and water source (lake; $\chi^2 = 1.61$, df = 3, $p = 0.656$) and (tap; $\chi^2 = 2.23$, df = 3, $p = 0.527$). Fisherfolk was cognizant of the need to curb microcystin toxicity. There was a significant difference ($p < 0.05$) in the occurrence of microcystin during the wet season compared to the dry season. Cyanophytes were the most significant ($p < 0.001$) group of phytoplankton. When ingested, microcystin has a long-term effect and therefore pollution control is crucial.

Keywords

Eutrophication, Fisherfolk, Lake Riparian Community, Algal Toxins

1. Introduction

Microcystin are algal toxin produced intracellularly within the algal cells; mainly from cyanobacterial blooms and released in water [1] [2]. Ordinarily, microcystin is cell-bound in healthy cyanobacterial cells but when cell lysis takes place in senescent blooms it results in to release of toxins into the water [3]. Cyanobacterial bloom emanates from nutrient loading into surface waters from wastewater and agricultural run-off [4] which is an increasingly severe worldwide ecological problem. This results in environmental deterioration and a public health threat [5] to human beings who depend on water and fish from such eutrophied water bodies [1] [6] and [7] asserted that blue-green algae are widely spread in many equatorial eutrophicated lakes, such as Lake Victoria because of the elevated temperatures which exacerbate algal growth and breakdown resulting in toxins emission.

Lake Victoria is of major concern in aquatic toxicology since it involves the risk of human exposure through direct consumption of contaminated water and through fish intake. The lake, being in the equatorial climate, the effect of warm climate increases the duration and frequency of toxic algal blooms [8], some producing toxins that are harmful to humans through fish and water consumption. The existence of microcystin in the waters of Lake Victoria has been documented [9] [10] [11] posited that the communities living along Lake Victoria are known to be major fish consumers thus they may easily exceed the average daily tolerance limit provided by World Health Organization (WHO) of 0.04 $\mu g \cdot kg^{-1}$ body weight [12] intake of microcystin through fish in their diet. It is therefore paramount to assess the exposure of microcystin through fish and water consumption in order to adequately gauge human exposure risk and advice accordingly.

There is a growing concern about the occurrence of microcystin in Lake Victoria and its harmful health effects on fauna and flora depending on the lake for survival. Lake Victoria pollutants are from both point and non-point sources which end in the lake resulting in lowered dissolved oxygen (DO) levels, increased nutrients load and turbidity [13]. Diseases resulting from exposure to microcystin depend on the exposure route. [14] and [15] identified water ingestion as a major exposure route to harmful cyanobacteria toxins in human and animals. These diseases can either be acute such as diarrhea, allergic reactions and throat irritation or chronic illnesses like those experienced in human carcinogen for liver and colorectal malignancies [16]. Consequently, these health risks should be addressed among vulnerable populations who have limited access to clean water. Several authors have documented the presence of microcystin in Lake Victoria [3] [7] [9] [10] [17]. Specifically, [7] and [18] conducted epidemiological studies to document acute and chronic human health effects caused by cyanobacteria and cyanotoxin with regards to the route and modes of exposure among other studies. However, no study has been done to assess knowledge, attitudes and practices of communities in Lake Victoria with regards to microcystin toxicity.

Our study delved into the understanding of the causes of harmful algal blooms in the lake as perceived by the inhabitants. We also went further to analyze the water samples to determine the levels of algal toxins present during the dry and wet seasons at different points of the lake.

2. Materials and Methods

2.1. Study Sites

This study was conducted in selected beaches of Homa Bay County (Mbita, Utajo and Homa Bay town), Kisumu County (Dunga), Siaya County (Anyanga and Uhanya) and Busia County (Mulukhoba) along Kenyan Lake Victoria side as indicated in **Figure 1**. The survey was both quantitative and qualitative and sampling of respondents was done purposively. To assess the knowledge, attitude and awareness of microcystin in the lake, a total of 90 semi-structured questionnaires, 11 Key Informant Interviews (KII) and seven Focus Group Discussions (FGD) were administered. The questionnaire assessed the socio-demographic characteristics of the respondent's awareness of microcystin toxicity, source of water, factors causing toxicity in the lake and trend of occurrence among others. The KIIs comprised the health practitioners in both public and private hospitals in the lake riparian communities. This was conducted to gauge their awareness and relationship of lake resource use in relation to microcystin related ailments reported in the health facilities. FGDs explored the linkages of microcystin toxicity with lake use.

This study followed the ethical considerations in research surveys involving human subjects [19] [20]. Prior permission and consent were sought before interviews and before taking any photographs, documentations on all activities involving respondents, work places or houses. Respondent's rights of freewill, privacy and confidentiality were protected during the interviews and data processing.

2.2. Water Sample Collection and Toxin Analysis

Water samples were collected from 14 different stations in the lake (Nyanza Gulf and open lake) during the dry and wet season and analyzed in the laboratory to find out the levels of algal toxins. Polyclonal Enzyme Linked Immunosorbent Assay (ELISA) kits were used for cyanotoxin analysis and measured colourimetrically in an ELISA plate reader at 450 nm. Samples were mixed with antibody solution and added to a 96-well microtitre plate. The contents were covered by parafilm, shook then incubated for 90 minutes at room temperature. After incubation, the parafilm covering was removed and contents vigorously shook into a

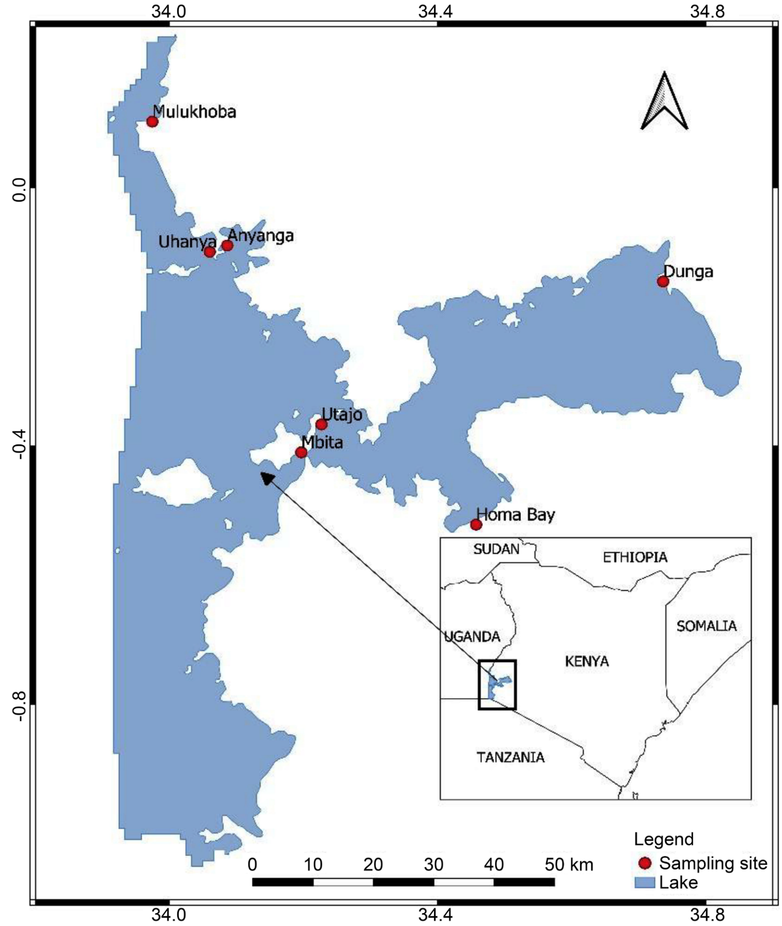

Figure 1. A map showing the sampling sites.

sink. The strips were washed three times with buffer solution, thereafter, microcystin-LR conjugate solution was added to the wells, covered and mixed once again and incubated for 30 minutes at room temperature. Finally, a stock solution was added to the wells before reading the absorbance at 450 nm using ELISA photometer.

2.3. Data Analysis

Data were analysed using Stata version 13.0 (Stata Corp, College Station, Texas, USA) and SPSS version 18.0. Descriptive analyses were done by use of counts, means, percentages, and ranges. Chi square (χ^2) test was used to test the differences and associations between categorical variables. Qualitative data were analyzed using Nvivo (QSR International) software version 10 to classify, sort and arrange information, and examine relationships in the data. Statistical significance was considered when $\alpha = 0.05$.

3. Results

3.1. Socio-Demographic Characteristics

Majority of the interviewed fisherfolk were youthful with an average age of 39.3

years and with gender composition of female being significantly higher ($p < 0.005$) than that of male as indicated in **Table 1**. About three quarters of the respondents (74.4%, n = 67) were married, 18.9% (n = 17) were single while a significantly low ($p < 0.005$) population, 4.4% (n = 4) and 2.2% (n = 2) were widowed and separated respectively. The education levels varied significantly with about a half (52.2%, n = 47) of the respondents having attained secondary education while a third (33.3%, n = 30) had primary education. About 13.3% (n = 12) had a certificate and a paltry (1.1%, n = 1) had a degree. Majority (63.3%, n = 57) of the respondents had a household size ranging between 4 - 6, 17.8% (n = 16) had 7 - 10 members, 15.6%, (n = 14) had 1 - 3 members while those with household of more than 10 were the least (3.3%, n = 3). Majority of the fisherfolk (82.2%, n = 74) had a father as the head of the household, 14.4% (n = 13) were headed by mother with only 3.3% (n = 3) were headed by older siblings or relatives.

Table 1. Socio-demographic characteristics of respondents.

	N	%	p value
Gender			
Female	48	53.3	
Male	42	46.7	
Mean Age	39.3		<0.005
Marital status			
Single	17	18.9	<0.005
Married	67	74.4	
Separated	2	2.2	
Widowed	4	4.4	
Education level			
Primary	30	33.3	
Secondary	47	52.2	
Certificate	12	14.4	
Degree	1	1.1	
Household size			
1 - 3	14	15.6	
4 - 6	57	63.3	
7 - 10	16	17.8	
>10	3	3.3	
Household head			
Father	74	82.2	
Mother	13	14.4	
Others	3	3.3	

3.2. Awareness of Microcystin and Human Induced Factors Causing Toxicity

Majority (73.3%) of the fisherfolk were aware of microcystin toxicity in the lake while the rest were not. However, there was no significant difference in the awareness of microcystin toxicity between men and women ($\chi^2 = 1.1$, df = 1, p = 0.293). FGDs and KIIs participants described microcystin as greenish and smelly and further confirmed that its intensity increased after rainy period, an instance they associated with human exposure reactions such as skin itchiness and rashes. Several human induced factors were reported to be causing toxicity in the lake (**Figure 2**). These included heavy rains (25.4%), agricultural run-off (22.3%), dumping of domestic or industrial waste (22.1%) release of untreated or partially treated sewage (18.9%), prolonged drought (7.2%) and other natural causes such as lake mixing (4.1%). There was no significant correlation between agricultural run-off and the level of education ($\chi^2 = 5.34$, df = 3, p = 0.149), dumping of domestic or industrial waste and the level of education ($\chi^2 = 1.03$, df = 3, p = 0.794) and release of untreated or partially treated sewage and the level of education ($\chi^2 = 2.47$, df = 3, p = 0.481).

3.3. Sources of Water

A significant proportion of respondents relied on lake (48.9%) and tap water (47.8%) for their domestic use while 16.8% and 7.8% sourced their water from borehole and through rain harvesting (**Figure 3**). However, there was no correlation between level of education and sourcing water from the lake ($\chi^2 = 1.61$, df = 3, p = 0.656), tap ($\chi^2 = 2.23$, df = 3, p = 0.527), borehole ($\chi^2 = 1.65$, df = 3, p = 0.885), and rain water harvesting ($\chi^2 = 1.59$, df = 3, p = 0.663).

3.4. Health Effects Associated with Consuming Water with Microcystin Toxicity

Respondents reported several health effects associated with microcystin toxicity in the lake which included skin irritation and rashes at 33.5%, stomach upset, diarrhea and vomiting (SDV) at 33.0%, throat irritation at 23.4%, eye irritation at 8.0%, and nausea at 2.1% as shown in **Figure 4**. The KIIs from health facilities reported that the most common clinical ailment symptoms were closely associated with high algal build-up in the lake and human exposure with intensity of reported cases increasing immediately after the rains; which was in agreement with FGDs responses.

3.5. How to Curb Microcystin Toxicity

Residents of the riparian communities proposed different methods on how to curb microcystin toxicity which included avoiding release of untreated and partially treated sewage (58.9%), government legislation on pollution at (57.8%), curbing agricultural run-off (40.0%) among other methods (14.4%) which included training of communities on the importance of conserving the environment (**Figure 5**). The same sentiments were echoed by FGDs respondents.

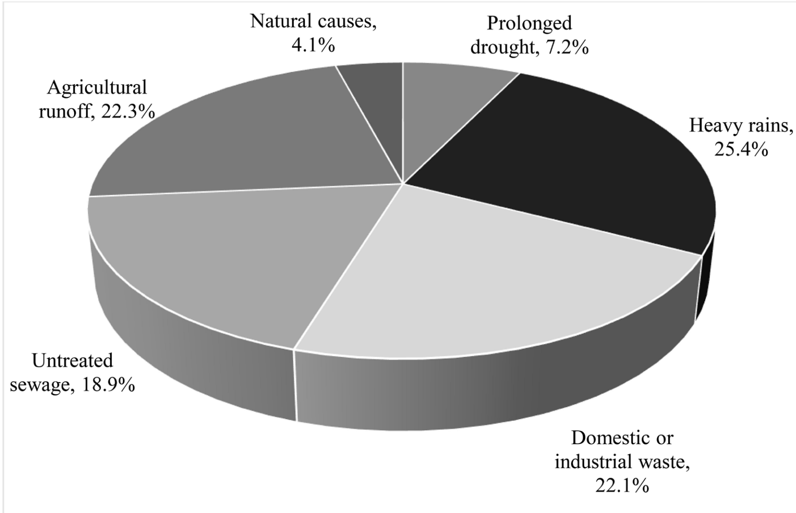

Figure 2. Human induced factors causing toxicity.

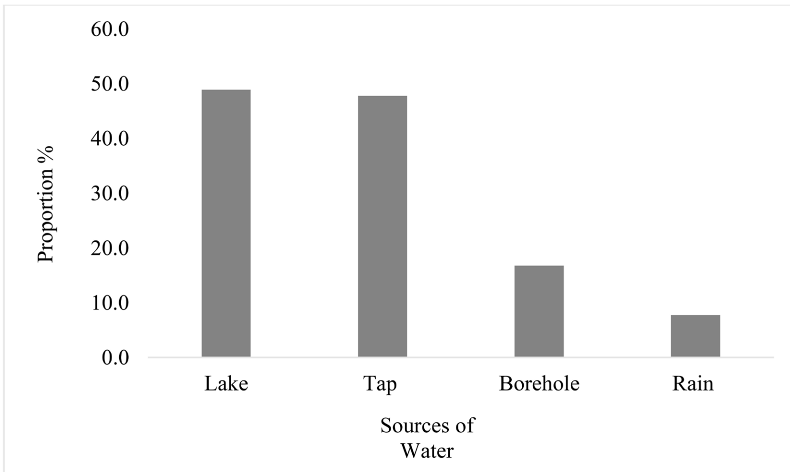

Figure 3. Sources of water among the residents.

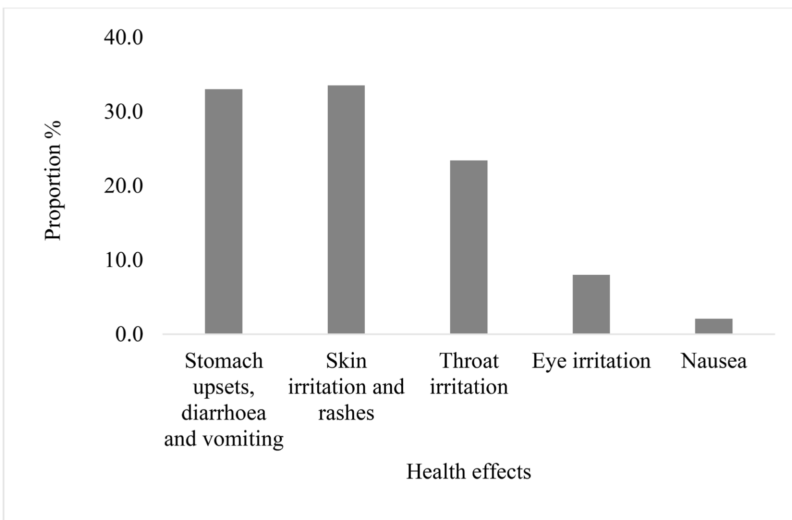

Figure 4. Microcystin human exposure symptoms.

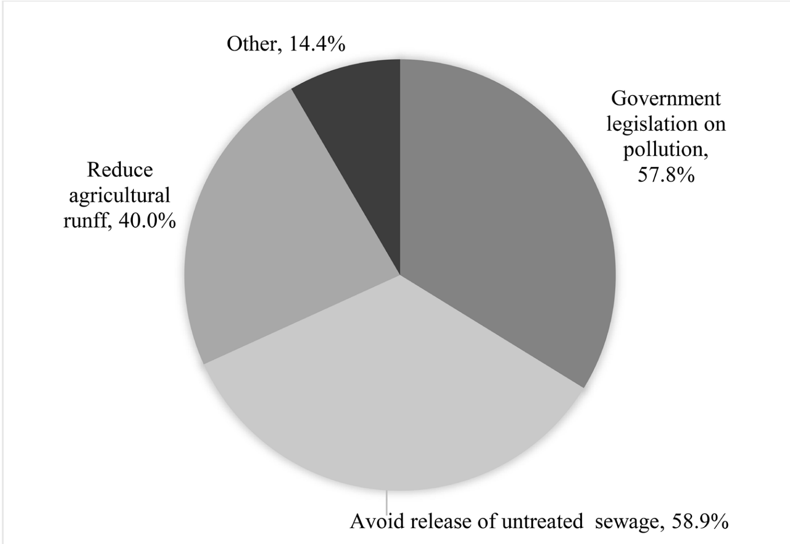

Figure 5. How to curb Microcystin toxicity.

3.6. Temporal Trend of Microcystin in Lake Victoria

The fisherfolks associated the wet season especially the long rains with high concentration of microcystin in the lake with occurrence being more significant ($p < 0.05$) when compared to the dry season. There was a notable sharp increase in the occurrence of microcystin between March and April with peak readings recorded in May. The least occurrence was recorded in September at only four. Only five respondents reported occurrence in October, November and December, an indicator of low occurrence during the dry months (**Figure 6**). The quantitative findings outlined were consistent with KIIs and FGDs responses that low occurrence of microcystin was recorded during the dry months.

3.7. Algal Toxins in the Water Samples

Cyanobacterial hepatotoxins (microcystin) were detected in most of the algal samples collected (**Figure 7**). However, an exception was Dunga A, Anyanga A, Anyanga B and Mulukhoba A, B and C during the dry season which was below the detection limit of 1 $\mu g \cdot L^{-1}$. Dunga B and Mulukhoba C during the wet season were also below the detection limit. St9 (Homa Bay sewage discharge) and Mbita East recorded the highest levels at 21.4 $\mu g \cdot L^{-1}$ and 13.1 $\mu g \cdot L^{-1}$ respectively during the dry season. During the wet season, Anyanga A recorded the highest detection limit of 23.4 $\mu g \cdot L^{-1}$ followed by St9 at 16.7 $\mu g \cdot L^{-1}$, Mbita East at 14.9 $\mu g \cdot L^{-1}$ and Anyanga B at 13.3 $\mu g \cdot L^{-1}$.

4. Discussion

Majority of the fisherfolk were in the middle age bracket, with a significantly higher female representation compared to males. Many residents join the fisherfolk community at an early age and this trend is associated with fishing, a family's main occupation [21]. [22] also noted that this age group forms the bulk

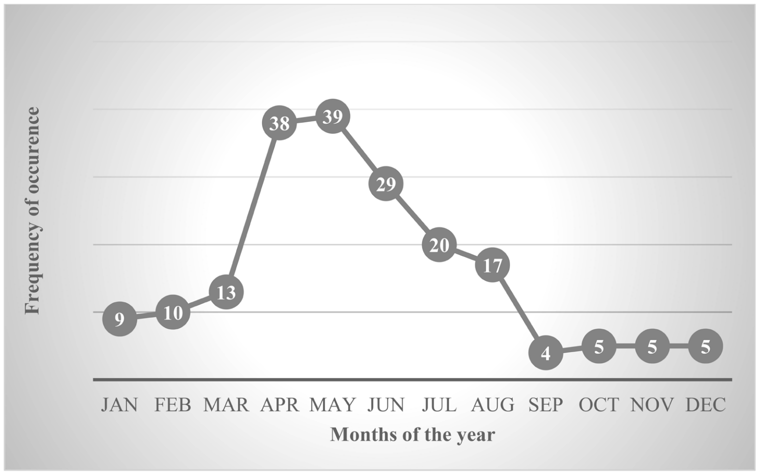

Figure 6. Temporal trend of microcystin in Lake Victoria.

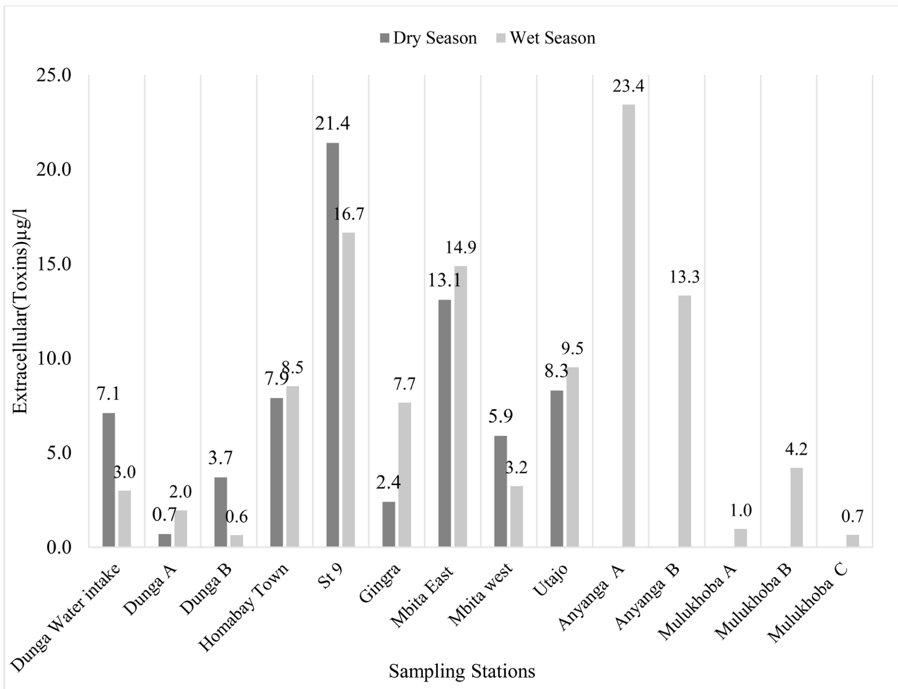

Figure 7. Level of Algal toxins in the water samples.

in the fishing industry since they are in their economic active years. Similar sentiments were echoed by [23] and supported by [24]. Half of the population had gained secondary education which is unlike earlier findings by [21] and [25] who found that many fisherfolk residents only had primary level of education. The fisherfolk were aware of algal blooms in the lake which were locally referred to as "twodo" In addition, they were aware of bathing and drinking exposure side effects but could not explicitly describe microcystin and their medically known short and long-term side effects to human beings. Even with the limited fisherfolk's awareness of the microcystin exposure effects, fishermen are constantly exposed during fishing. Additionally, fisherfolk community reported to be using untreated water for various domestic uses. This was despite their ability to detect microcystin build-up through taste and colour of water. [8] and [26] reported that microcystin were found to respond to eutrophication through population increase in the form of blooms, scums and mats which affects the quality of drinking water. In addition, the water was found to be greenish, smelly and when used for bathing caused skin irritation. [7] noted that the greenish colour was an evidence that cyanobacteria member was present in the sample and use of untreated lake water was causing several clinical symptoms such as vomiting and skin irritation. This emanates from some species of cyanobacteria which have the ability to produce toxins. Consequently, [27] highlighted that majority of blooms are caused by *Microcystis* sp., especially *Microcystis aeruginosa*.

The concentration of microcystin is determined by exposure route and the levels absorbed in the human body [7] [16] which depends on the period of exposure through bioaccumulation. Some of the exposure routes include drinking water, swimming and fish intake. Chronic health effects include liver cancer and colorectal malignancies which are fatal [15] [26] [28] [29] reported a positive association between the incidence of primary liver cancer and exposure to drinking water contaminated with cyanobacteria. However, in this study, it was very difficult for health practitioners to link cancer related illnesses with intake of lake water since microcystin exposure ailments are non-specific in nature and therefore diagnosis becomes a problem. Consumption of water and aquatic animals containing microcystin represents potential risk to human health. This is because microcystin usually bio-accumulates in aquatic animals [30] and later transferred along the food web to higher trophic levels and finally to human beings [31]. In most of the sampled stations microcystin levels were far beyond the recommended rates during both the dry and wet season posing a major health risk to riparian community. These findings are in agreement with [10], who observed species of cyanobacteria in Lake Victoria in all the months of the year. Microcystin exposure from drinking water affects many populations consuming water from polluted sources. For example, [32] noted that many inhabitants exceeding the Tolerable Daily Intake (TDI) results from the consumption of untreated drinking water.

5. Conclusion

The communities living around the lake have been negatively affected by the presence of microcystin in the water which they depend on for their domestic purposes. There should be frequent monitoring of microcystin species concentration levels at various locations within the lake by seasons. This will help to understand the levels and take the necessary measures to control the same. The involvement of the government and the private sector is vital in providing solutions to microcystin toxicity in the lake; one major approach is the provision of clean water at homesteads and public utilities. In addition, controlling human-induced factors causing toxicity will be of great significance. This is to be coupled with community sensitization and cultural shifts in water use.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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