PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER IN SELECTED LOCATIONS IN LAKE VICTORIA, TANZANIA

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ABSTRACT

A study conducted during the period of March/April 2002 aimed at measuring physical and chemical parameters in Tanzanian portion of Lake Victoria. Temperature and conductivity values were homogeneous among and within the study stations. Levels of dissolved oxygen (DO) ranged from 4 - 9 mgl^{-1} and there was significant difference between stations ($P < 0.05$). Water transparency was poor (< 2 m secchi depth) and differed from one sampling station to another. Ammonium nitrogen (NH_4^+-N), with few exceptions, showed the highest concentrations both at the bottom and near-surface followed by total phosphates (TP), nitrate nitrogen (NO_2+NO_3^--N), nitrite nitrogen (NO_2^--N) and Soluble Reactive Silicon (SRSi). Concentrations of $NH4^+$-N, TP and SRSi were high at bottom waters and the reverse was true for NO_2+NO_3^--N and NO_2^--N. Differences in nutrients and physical water parameters among sampling stations were statistically significant ($P < 0.05$). However, temperature and nutrient levels at studied areas were higher than that of 50 years ago and the trend reversed for DO and transparency. This indicates that Lake Victoria is receiving organic materials from the catchment area leading to the decline of water quality. Long-term efforts for rehabilitation, conservation and sustainable management of the lake are suggested.

INTRODUCTION

The rapid increase in human population in Lake Victoria catchment area has had significant impacts on the dynamics of the lake water resources in the last few decades (Hecky 1993). Municipal activities discharge poorly treated wastes into the lake that directly stimulate phytoplankton productivity (Hecky and Bugenyi 1992). The algal blooms and turbidity do not only affect transparency of water but also reduce photosynthetic processes in the bottom waters and hence may contribute to the anoxic conditions. Lack of oxygen and presence of algal blooms in water cause fish to suffocate and fish kills may occur as reported by Kaufman (1992) due to hypotoxicity and phytotoxicity (Ochumba 1987, Ochumba 1990). Studies have shown that nitrogen concentrations in lake water have been increasing since 1950s (Hecky 1993) while silicon levels have declined by the factor of ten, particularly in the epilimnion of offshore regions (Kilham and Kilham 1990). Discharge of excessive wastes from the catchment area has impacts on the water clarity, DO, population dynamics of phytoplankton and fish. In recent decades, diatoms have been replaced by cyanobacteria as the dominant group of planktonic algae (Kling et al. 2001). Considering the multiple environmental stresses that are facing the lake at the moment, long-term sustainability and productive fishery is questionable.

Few ecological studies related to physical and chemical characteristics of water in Lake Victoria (Worthington 1930, Talling 1966, Akiyama et al. 1977, Hecky 1983, Ochumba 1987, Ochumba 1990) have been conducted. However, many studies have focused on fish introductions, changes in fish compositions, macrophytes and algal blooms. There is need for comprehensive data and information on water quality. Changes in biota, environment and possible causes of these changes have been appreciated as mandatory for proper and workable management strategy for the restoration of the lake ecosystem and sustainable utilization of the lake resources.

Although efforts have been made to curb excessive influx of wastes and nutrients from the catchment area into the lake, little has been achieved. This paper gives an account of physico-chemical status of water in selected areas of Lake Victoria in Tanzania.

MATERIALS AND METHODS

Study Area

Lake Victoria is the second largest freshwater body in the world with a surface and catchment areas of 68,800 km^2 and 258,700 km^2 respectively. The lake is shared by three East African countries, Kenya (6%), Uganda (43%) and Tanzania (51%). Much of the lake is less than 40 m deep and the deepest part, 60-90m, is in the northeast.

Sampling was conducted in the Tanzanian part of Lake Victoria from March to April 2002. Sampling stations were Lamadi, Bulamba, Mwanza Gulf, Bawmann's Gulf, Shirati, Rubafu, Mara and Mori bays (Figure 1).

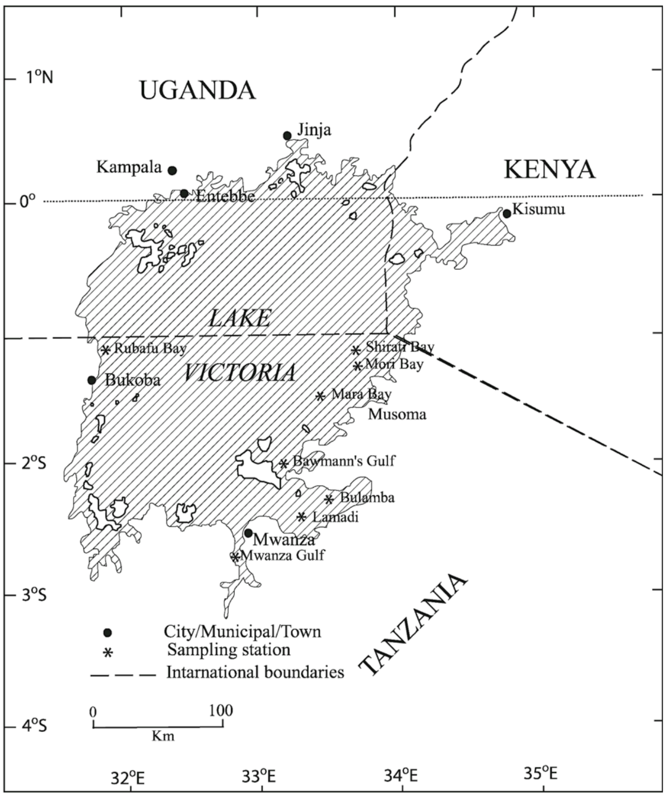

Figure 1: Map of Lake Victoria showing sampling stations

Sample collection

In situ measurements for conductivity, temperature and dissolved oxygen at the surface and bottom waters were made using a Seabird profiler. Secchi depth (transparency) was measured with a 25 cm diameter painted black and white secchi disc. The disc was lowered along the side of the boat away from the direct sunlight and the depth of disappearance was recorded. For accuracy, the seabird was calibrated (only for DO using the Winkler titration) before and after each sampling trip using recommended standards as described in APHA (1992).

At each sampling station, water samples were collected at the surface (0 – 0.5 m) and bottom depths of the lake using a 1-litre capacity plastic Van Dorn sampler. Water samples were stored in polyethylene bottles, fixed using H_2SO_4 and kept at 4^OC in a refrigerator inboard the survey boat. Bottom water samples were collected from 3 – 18 m depth depending on the maximum depth of a station. In the laboratory, samples were divided into two portions. The first portion was filtered through 47 mm GF/C filter papers. The filtrates were kept for analysis of dissolved nutrients (NH_4^+-N, NO_2+NO_3^--N, NO_2^--N and SRSi) using spectrophotometric standard methods as outlined in APHA (1992). NH_4^+-N was analyzed using manual phenate method, NO_2^--N using colorimetric method, NO_2+NO_3^--N by cadmium-reduction method and SRSi using atomic absorption spectrophotometry. The second portion, the unfiltered sample, was used to analyze phosphates (PO_4^+-P) as TP using the ascorbic-acid method as described in APHA (1992).

Data analysis

Differences in chemical and physical water quality parameters among and within sampling stations were tested using Kruskal-Wallis Test (Friedman's test) followed by Dunn's Multiple Comparison Tests (Zar 1984).

RESULTS

Mean values of temperature and DO levels differ much neither within nor among the sampling stations (Table 1). Though conductivity values differed from one sampling site to the other, still the difference within the site was negligible. Lower values for temperature, DO and conductivity were recorded at greater depths /bottom waters. Water temperatures ranged from 25.8^OC (at 0.2 m in Mara Bay) to 24.6^OC (at 6 m in Rubafu Bay) while DO ranged from 8.9 mg/l (at 0.2 m in Bawmann's Gulf) to 4.4 mg/l (at 18 m in Mori Bay). Conductivity ranged from 94.2 μ at 0.5 m (Shirati Bay) to 110.5 μS/cm at 0.5 m (Mwanza Gulf). Conductivity and DO did not differ statistically ($P > 0.05$) either among or within the sampling stations.

Water temperatures were higher at the surface than at the bottom waters by 1 degree for Mara and Rubafu bays while in other sampled areas, values were almost stable in the surface and bottom waters. Temperature ranged from 24.5 ^oC (at 0.5 m in Lamadi) to 25.8^OC (at 0.2 m in Mara Bay) and 24.4^OC (at 6 m in Lamadi) to 25.2 ^oC (at 4 m in Mara Bay) for the surface and bottom waters respectively. Differences in temperature within and across study sites were statistically not significant ($P > 0.05$).

The highest secchi depths were recorded at Mara Bay followed by Mori Bay and Shirati Bay. Lower secchi depths (≤ 1.7 m) were measured in the Mwanza Gulf, Bawmann's Gulf, Lamadi and Bulamba whereas the lowest secchi depth was recorded in the Rubafu Bay (0.5 m) (Table 1). Differences in secchi depths between Bawmann's Gulf and Mara Bay, between Bawmann's Gulf and Mori Bay, between Rubafu Bay and Mara Bay and between Rubafu Bay and Mori Bay were statistically significant (KW = 24.95, P = 0.003).

Table 1. Physico-chemical characteristics of water in Lake Victoria at various sampling stations

Parameter	Depth (m)	Temp (^{0}C)	DO (mg/l)	Cond. (μS/cm)	NH_4 (μ g/l)	NO_3 (μ g/l)	NO_2 (μ g/l)	TP (μ g/l)	SRSi (μ g/l)	Transparency (m)
Lamadi	0.5	24.5 ± 0.0	5.5 ± 0.0	95.7 ± 0.6	234.8 ±13.2	31.0 ± 15.2	8.8 ± 0.7	100.2 ± 3.2	1.0 ± 0.1	1.7 ± 0.2
	6	24.5 ± 0.0	5.5 ± 0.1	95.3 ± 0.1	256.6 ± 7.7	28.8 ± 11.4	4.3 ± 0.5	101.8 ± 6.8	10.8 ± 1.6	
Bulamba	0	24.7 ± 0.0	5.7 ± 0.0	94.2 ±0.03	101.6 ± 2.4	259.3 ±10.4	24.8 ± 4.5	119.3 ± 3.5	1.0 ± 0.12	1.5 ± 0.1
	10	24.7 ± 0.0	5.7 ± 0.03	94.3 ± 0.1	89.5 ± 0.8	313.5 ±21.7	35.9 ± 3.7	164.0 ±15.5	1.0 ± 0.2	
Bawmann’s Gulf	0.2	24.8 ± 0.0	8.9 ± 0.1	106.1 ±0.1	205.1 ± 6.1	29.9 ± 0.6	3.4 ± 0.8	82.6 ± 0.7	7.6 ± 8.7	0.7 ± 0.1
	3	24.8 ± 0.0	8.8 ± 0.1	106.0 ±0.3	260.4 ± 1.6	26.1 ± 0.7	1.5 ± 0.04	89.5 ± 1.1	2.5 ± 1.2	
Mwanza Gulf	0.5	25.2 ± 0.1	7.4 ± 0.1	95.8 ± 0.3	141.4 ±43.7	28.5 ± 4.5	5.1 ± 0.7	96.9 ± 1.8	1.9 ± 0.1	1.7 ± 0.1
	15	25 ± 0.0	6.6 ± 0.0	95.1 ± 0.1	255.5 ±93.4	28.3 ± 4.3	2.6 ± 0.03	87.2 ± 1.6	2.2 ± 0.4	
Mara Bay	0.2	25.8 ± 0.0	6.5 ± 0.1	96.5 ± 0.2	218.1 ± 5.4	51.4 ± 1.6	21.3 ±3.3	110.1 ± 5.6	1.2 ± 0.1	2.4 ± 0.1
	4	25.2 ± 0.5	6.4 ± 0.1	95 ± 0.9	156.5 ±51.5	26.2 ± 4.7	2.4 ± 0.5	129.8 ± 27.2	1.5 ± 0.1	
Mori Bay	0.5	25 ± 0.0	6.4 ± 0.1	96.1 ± 2.7	128.2 ±19.6	21.7 ± 1.4	1.6 ± 0.2	98.6 ± 6.9	1.4 ± 0.5	2.2 ± 0.3
	18	24.5 ± 0.0	4.4 ± 0.1	110.5 ±25.2	148.5 ±24.3	20.8 ± 1.8	0.7 ± 0.1	133.8 ± 4.2	3.5 ± 1.6	
Shirati Bay	0.5	25.4 ± 0.0	8.8 ± 0.04	97.7 ± 0.1	128.2 ±23.1	21.7 ± 4.8	4.0 ± 2.1	88.8 ± 13.4	1.4 ± 0.1	2.1 ± 0.1
	15	25.0 ± 0.1	7.1 ± 0.3	94.9 ± 0.2	120.6 ± 3.4	26.0 ± 4.2	2.2 ± 0.9	91.3 ± 13.8	1.5 ± 0.3	
Rubafu Bay	0.5	25 ± 0.0	7.2 ± 0.2	96.8 ± 0.1	186.7 ±52.9	19.3 ±1.5	1.8 ± 0.3	83.9 ± 5.1	1.9 ± 0.7	0.7 ± 0.3
	6	24.6 ± 0.2	6.3 ±0.6	95.7 ± 0.4	194.2 ± 4.5	21.5 ± 1.5	1.5 ± 0.3	85.6 ±20.7	2.4 ± 0.3	

Mean values of TP were high at bottom waters in all sampling sites except for Mwanza Gulf. It was found that Bulamba station had the highest value of TP (164.0 ± 15.5 μg/L) followed by Mori Bay and Mara Bay in bottom waters (Table 1). There were significant differences ($P < 0.05$) in TP concentrations between Mara and Rubafu sampling stations ($KW = 20.57$, $P = 0.005$). Vertical variations in the concentration of TP were not significant ($P > 0.05$).

Mean values of $NH4^+$-N in bottom water samples were higher than that of surface in all sampled stations except for Bulamba, Mara Bay and Shirati Bay where the trend reversed (Table 1). There was significant difference ($Fr/\chi^2 = 8.4$, $P = 0.009$) in ammonium concentration between the surface and bottom waters in Rubafu Bay. Kruskal-Wallis Test showed that differences in ammonium concentration between Bulamba and Lamadi, between Lamadi and Shirati were statistically significant ($KW = 25.25$, $P = 0.0007$).

Mean values of NO_2+NO_3^--N were very high both at the surface (259.3 ± 10.4 μg/L) and at the bottom (313.5 ± 21.7 μg/L) in Bulamba while in Mara Bay, nitrate concentrations were 51.4 ± 1.6 μg/L and

26.2 ± 4.7 μg/L at 0.2 m and 4 m respectively. Conversely, nitrate concentrations of water samples from other sampling stations ranged from 19.3 μ to 31.0 μg/L. Difference in nitrate concentrations at different depths within sampling stations was not statistically significant ($P > 0.05$). However, nitrate concentrations between Bulamba and Mori, Bulamba and Shirati, and Bulamba and Rubafu were statistically different ($KW = 22.34$, $P = 0.002$).

Similarly, high concentrations of nitrite were recorded at Bulamba at 10 m (35.9 ± 3.7 μg/L) and 0 m (24.8 ± 4.5 μg/L). Mara Bay showed a concentration of 21.3 ± 3.3 μ g/L (0.2 m depth) and 2.4 ± 0.5 μg/L (4 m depth) while in other sampling stations concentrations were low, ranging from 0.7 to 8.8 μg/L. Bottom waters had lower concentration than surface waters except for Bulamba (Table 1). The difference in nitrite concentrations between Bulamba and Mori was statistically significant ($KW = 20.9$, $P = 0.004$) whereas differences in nitrite concentrations at the surface and bottom waters within sampling station were not statistically significant ($P > 0.05$).

Mean values of SRSi were high at bottom than surface waters in all sampled areas except for Bawmann's Gulf. The highest concentration (10.8 ± 1.6 μg/L) was recorded at Lamadi (bottom waters of 6m depth) while the lowest (1.0 ± 0.1 μg/L) was recorded at the same station of surface waters (0.5 m).

DISCUSSION

Oxygen concentrations in water bodies are not only a measure of environmental health of the aquatic ecosystem, but are also the lifeline of the aquatic life. Low oxygen levels at the bottom waters found by the present study were associated with several factors. For example, a slight difference in temperature with depth would make the water column stable thereby reducing re-oxygenation through mixing particularly at shallow waters (Worthington 1930, Wetzel 1983). Decomposition of the organic materials from sewage discharge and dead algae depletes the dissolved oxygen in lakes especially at bottom layers. Surface waters had high levels of DO possibly as a result of photosynthetic processes and dissolved atmospheric oxygen.

The concentrations of DO obtained under this study are similar to those reported by Hecky (1993) and Talling (1966) who found out that the water column of Lake Victoria is becoming more stable and total circulation of water is more limited with increasing depth. However, the surveyed areas had oxygen levels above 3 mg/L, which is considered as a critical level for survival of major commercial fish species (Wetzel 1983). Generally, observed levels of DO were not low to the extent of affecting the fishery and aquatic life but with time and continued addition of biodegradable materials, critical DO levels for survival of fish stocks will be reached. The insignificant differences in DO and temperature at different depths within and among sites might be attributed to shallowness of the surveyed areas.Akiyama et al. (1977) reported temperature values ranging between 22.0OC and 24.0OC in Mwanza Gulf, which are lower than the present values. The increased lake water temperature could be attributed to increased suspended matter in the lake. Increased heat in lake water results in increased stability of stratified water column and hence reducing mixing depth (Wetzel 1983).

Conductivity of waters varied slightly among and within the sampling stations. This shows that water in the sampled areas contained similar dissolved nutrients that are responsible for carrying electric current. The highest value that were recorded at Mwanza Gulf may be attributed to the gulf being closer to urban centres and receives effluents from municipal and industrial activities, which have high capacity for electric currents. Shirati Bay on the other hand receives small amounts of effluents from Shirati town.

High degrees of turbidity (corresponding to low transparency) are attributed to the abundance of phytoplankton and stirring of water by regular wind action (pers. observ.) that leads to re-suspension of bottom silt. It might also be attributed to an increase in human population (Bootsma and Hecky 1993) in the catchment area with subsequent increase in anthropogenic input of materials to the lake. Numerous rivers draining into Speke Gulf are among the possible reasons causing observed lower secchi depths recorded at Lamadi and Bulamba. Furthermore, lower secchi depth observed at Rubafu Bay is likely due to suspended materials brought by Kagera River, which is the largest river entering Lake Victoria at Rubafu Bay. These materials are accompanied with nutrients that obviously favour the growth of phytoplankton. This supports the findings reported by Lyimo and Sekadende (2003) that the area is rich in phytoplankton dominated by blue-green algae.

It is important to note that the concentration of nitrogen compounds especially ammonium and nitrate were much higher than other measured nutrients. The present levels of nitrates are several times higher than those reported by Ochumba and Kibaara (1989), Mavuti and Litterick (1991). The drastic increase in nitrogen, which is considered as a limiting nutrient in Lake Victoria (Talling and Talling 1965), is due to excess input of organic materials into the lake. This, in turn, accelerates algal growth leading to development of algal blooms and subsequent decrease in water transparency.

Although inputs of nitrates are mainly via run-off from fertilized agricultural land and sewage outflows (Ochumba and Kibaara 1989), rainfall and re-mineralization processes are other important sources (Wetzel 1983). It is natural to assume that the nutrients like nitrogen and phosphate are added into the lake through land runoff caused by rainfall (Wetzel 1983). According to Tanzania Meteorological Agency (2002), March/April (the sampling period for the present study) is a rain season in Lake Victoria basin. Rainfall during this period was high and this probably contributed to the observed high concentration of nitrate. An increase in cyanobacteria could also contribute to an increase level of nitrate through N-fixation. The findings of present study suggest that all these processes are taking place in Lake Victoria. When long-term nitrate trends are considered, there is an overall increase while the reverse is true for secchi transparency (Worthington 1930, Talling 1966, Ochumba and Kibaara 1989, Ochumba 1990, Kenyanya 2000, Kishe 2002).

Though soluble reactive silica (SRSi) values were found to be low, higher concentrations were recorded in the bottom waters. Similar observations have also been reported in Kenyan waters (Kenyanya 2000). However, Talling (1966) reported silicate (SiO_2) values of 4 - 4.5 mgl^{-1} in the open lake areas which is much lower than the present data and those reported by Kenyanya (2000). Diatoms, which normally use silica for their cellwall formation, have now been replaced by cyanobacteria, hence, their density was low (Lyimo and Sekadende 2003) compared to the numbers reported by Talling (1966), Ochumba and Kibaara (1989) and Crul (1995). In addition, lower SiO_2 values in the surface waters are attributed partly to high uptake by diatoms (Crul 1995) that have been found to inhabit the pelagic zones of the lake (Ochumba and Kibaara 1989).

The high concentrations of TP recorded in surface waters are usually associated with high photosynthetic rates resulting in occurrence of high concentration of particulate phosphorus. Similar results have been reported in the Kenyan waters (Ochumba and Kibaara 1989, Kenyanya 2000) and Ugandan waters (Godfrey 1999). Communities at the vicinity of some sampling stations engaged in agricultural activities. Inundations of farmlands that occur during the rain seasons contribute large amount of sediments and nutrients (i.e phosphates and nitrogenous compounds) to the lake.

There are numerous measures that have been taken to improve water quality in Lake Victoria. However, little has been achieved. The algal blooms (Lyimo and Sekadende 2003), high turbidity and invasion of water hyacinth in some study areas associated with high nutrient loads in the lake and have had significant consequences on the aquatic life by changing the chemistry of the water (e.g. O_2 depletion). Incidences of occasional outbreaks of water borne diseases in areas close to the lake is a testimony of increasing human health risks due to contamination of water. Though blue babies disease is not common in the region but with these levels of nitrates in the water, children may suffer due to high nitrate intake, as Lake Victoria is the sole source of water in the region for household uses including drinking.

Based on data presented in this paper, there is need for monitoring of the limnological characteristics in aquatic ecosystems of Lake Victoria basin in order to understand the trophic dynamics of the ecosystem and to come up with relevant management strategies.

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