Lakes & Reservoirs: Research and Management 2009 **14**: 247–257

Trends in health risks from water-related diseases and cyanotoxins in Ugandan portion of Lake Victoria basin

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Abstract

Studies to examine the prevalence of water-related diseases, cyanobacteria toxins and other health risks at landing beaches in the Ugandan portion of the Lake Victoria basin were carried out. Based on surveillance studies and other data sources in the region, water samples were analysed for indications of faecal contamination. The coliform numbers were generally high for most sampling sites, indicating significant water contamination. The wet seasons exhibited significantly higher coliform counts than the dry seasons for all lakeshore sample sites. This seasonal variation in coliform counts correlated positively with the incidence of waterborne diseases, which are typically higher in the wet season. The water supply for domestic consumption for the Lake Victoria riparian communities is mainly the lake itself. The most prevalent diseases associated with the landing sites include malaria, dysentery, diarrhoea and bilharzia. Malaria was most prevalent, followed by dysentery, in all the studied districts. Many people in the catchment dispose of faecal wastes in lakeshore area bushes, or in polythene bags, contaminating water sources with faecal material, and resulting in waterborne diseases. The vulnerability of lakeside communities to water-related diseases is further aggravated by low accessibility to health facilities and personnel. Further, cyanobacteria (potentially toxic to humans and animals) dominate other algal species in Lake Victoria, contributing >50% of the algal biomass. Algal blooms occurred frequently in Murchison Bay, a source of drinking water for the city of Kampala and surrounding urban centres. Algal blooms can cause unpleasant odours and tastes in domestic water supplies, clog pump and machinery filters, increase chlorine demands for water disinfection, and necessitate more complex and expensive treatment processes. The findings of this study suggest improved water quality, changes in sanitation and hygiene behaviour could significantly reduce the prevalence of water-related diseases and cyanotoxins in the Ugandan portion of the Lake Victoria basin.

Key words

cyanotoxins, health risks, Lake Victoria, Uganda, water-related diseases.

INTRODUCTION

Similar to many developing countries, Uganda is characterized by a high population density, accompanied by a relatively poor infrastructure. The existing sanitary facilities and practices in the urban centres and many rural settlements cannot protect the population from waterborne diseases related to contamination of surface water sources with human wastes. Waterborne diseases (e.g. cholera and typhoid fever) have become rampant as a result.

In addition to introducing bacteria (coliform) of faecal origin, faecal pollution also introduces nutrients into a waterbody, thereby accelerating the eutrophication process and causing explosive growth of algal species, which can themselves be further health risks (Muthoka *et al.* 1998). Faecal pollution also implies a high risk of contracting waterborne diseases if the water is used for drinking purposes without pre-treatment (Odada *et al.* 2004; Wandiga *et al.* 2005; Yanda *et al.* 2005). Under the World Health Organization (WHO) guidelines, the bacterium *Escherichia coli* should not be detected in a given 100 mL sample of drinking water (Havelaar *et al.* 2001). Thus, it is critical that human faeces be safely disposed,

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Accepted for publication 20 June 2009.

Doi: 10.1111/j.1440-1770.2009.00407.x

to reduce the pathogen load to the ambient environment (Huttly *et al.* 1997).

Cyanobacteria dominate other algal species and contribute a larger fraction (>50%) of the algal biomass (Mugidde *et al.* 2003) in Lake Victoria. Cyanobacteria are potentially toxic to humans and animals, and can also degrade the ecological and aesthetic values of water. They also have been reported to poison wild animals (e.g. fish, kangaroos and birds (Krienitz *et al.* 2003; Sekadende *et al.* 2005). The three main toxin-producing blue-green algae in the tropical regions of the world are *Anabaena, Microcystis* and *Cylindrospermopsis.* Algal blooms also can cause unpleasant odours and tastes in domestic drinking water supplies, clog pump and machinery filters, and increase chlorine demands, leading in turn to increased trihalomethane precursors that can result in increased chloroform and other potential carcinogens in treated water supplies, and increase the costs of operating water treatment plants.

After malaria, bilharzia (schistosomiasis), caused by a blood fluke of the genus *Schistosoma*, is the second most prevalent tropical disease in Africa. Snails are the intermediate hosts of the genus *Schistosoma*. *Schistosoma mansoni* is responsible for all the cases in Uganda (Kadama *et al.* 2001). The prevalence of schistosomiasis is typically highest near the lakeshore and along large rivers (Odongo-Aginya *et al.* 2008). No transmission of this disease occurs at altitudes >1400 m a.s.l., or where the total annual rainfall is <900 mm, criteria which can be used to help estimate the general population at risk from schistosomiasis (Kabatereine *et al.* 2004).

Ninety-three per cent (93%) of the total population in Uganda is at risk from malaria, with *Plasmodium falciparum* being responsible for >95% of all cases. The major malarial vectors are: *Anopheles gambiae* s.l. (and within the complex, mainly *A. gambiae* s.s.) and *Anopheles funestus*. The number of reported malaria cases has increased steadily over the past 14 years (MoH 2005). It is estimated that up to 100 000 deaths occurring annually in Urganda can be attributed to malaria, most being children <5 years old. The vector mosquitoes require access to standing water to complete their life cycles, with their eggs being deposited, and their larvae growing to adults, in water.

The first HIV/AIDS case was diagnosed in Uganda in 1982. Since that year, >2.2 million people have been infected, with ≈838 000 having since died, leaving behind nearly 1.7 million orphans. HIV/AIDS has caused several serious socioeconomic impacts, including straining the nation's health system, disrupting the socioeconomic structure and reducing the productive capacity. It also has exacerbated poverty at the household and community levels. The number of cumulative AIDS cases has continued to increase as a result of a large pool of HIV-infected people who fell sick (UNICEF-IRC 2002). The first two cases of AIDS identified in Uganda in 1982 were from the Rakai District, on the shores of Lake Victoria. Although not a waterborne disease *per se*, HIV/AIDS is extremely prevalent in the fishing communities around the lake, with the high mobility of fisher folks being a significant vector in maintaining and spreading the disease around the lake perimeter. The relationship between water quality and human health in the Lake Victoria basin is presented in Figure 1. This study discusses trends in the prevalence of water-related diseases and cyanotoxins in the Ugandan portion of the Lake Victoria basin from the year 2002 to the beginning of 2009.

METHODS

A rapid survey of five landing sites was undertaken in this study in October 2002, with water sampling and review of reported diseases at the nearest health centres. This study was intended to analyse the prevalence of disease and sanitary conditions at selected landing sites around the lake. The studied landing sites were: (i) Kasensero (Rakai District); (ii) Dimo (Masaka District); (iii) Kiyindi (Mukono District); (iv) Bwondha (Mayuge District); and (v) Dorwe (Bugiri District). These sites are identified in Figure 2 (in Roman numerals), as well as other landing sites studied in the other sections of this study (in Arabic numerals).

This study targeted local officials as key informants at the landing sites on the lake, and health workers of the most frequently visited health centres in the communities. An interview protocol was used to investigate the general population size, basic economic activities, health problems and existing health facilities, sanitary and hygiene conditions, water sources and waste disposal facilities, among others. On-site data collection was to verify responses from respondents on hygiene and sanitation issues, water characteristics and waste disposal facilities. Water samples were collected from the available water sources and analysed for physical, chemical and pollution indicator microorganisms (American Public Health Association (APHA) 1998). Water sources, which varied between sampling sites, included the lakeshore, springs, shallow and, where they existed, deep wells.

A separate study on the prevalence of schistosomiasis around the riparian districts of the Ugandan portion of the Lake Victoria basin also was carried out in 2002. This latter study addressed the intensity and extent of schistosomiasis in the fisher folk communities at the Lake Victo-

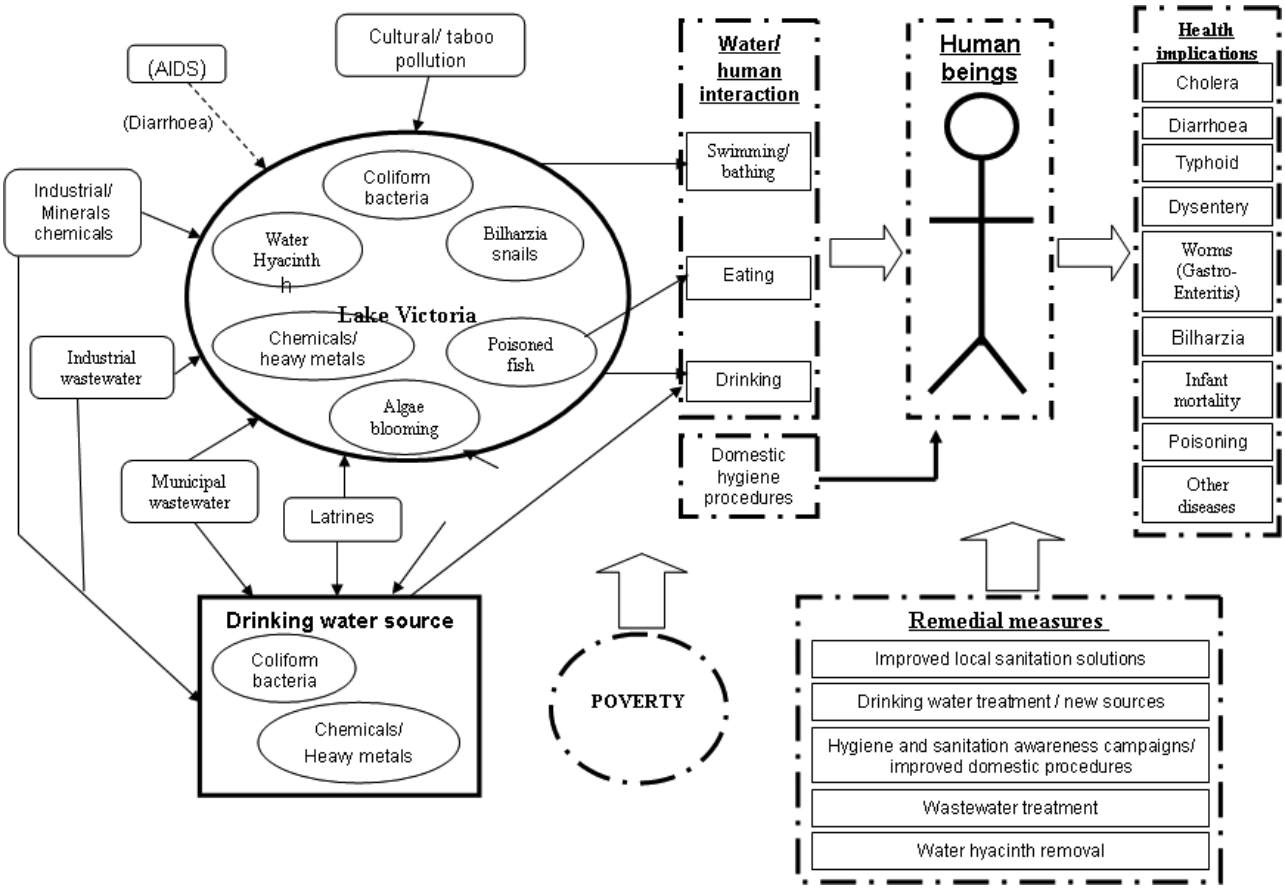

Fig. 1. Simplified schematic relations between water quality and human activities in Lake Victoria (large circle) and human health (box on right).

ria shores, in relation to the obligate snail populations. This latter study was carried out in six districts around Lake Victoria, some being different from those studied before. These districts included Mukono, Jinja, Mayuge, Iganga, Bugiri, Busia and Kalangala. Two hundred and seventy-one adult respondents were randomly selected from 17 landing sites in the study districts mentioned (see Arabic numerals in Fig. 2). Questionnaires were administered, and urine, stool and blood samples of the respondents were analysed. The issues investigated included intestinal infestations, environmental public health, water and sanitation and nutritional aspects. The symptoms addressed included persistent abdominal complaints, blood-stained stools and bloody diarrhoea, as indicators of health and nutritional status. Key contributing issues were the availability of latrines and clean water, and food consumption.

Other studies to characterize toxic cyanobacteria in Lake Victoria also were reviewed (Canadian International Development Agency (CIDA) 2002; Okello 2004; Sekadende *et al.* 2005). Okello (2004) characterized the occurrence of cyanobacteria species in relation to environmental conditions, and determined cyanotoxin production in Ugandan freshwaters, including Lake Victoria. The sampling sites on Lake Victoria were Murchison Bay, Napoleon Gulf and Jinja wetland finger ponds. Okello (2004) collected samples from 1 m depth, using a 2 L horizontal Van Dorn sampler. Net samples were taken by vertical-net hauls, using plankton nets with 30 μm mesh size. Cyanobacteria species determination was performed microscopically, with 192 strains being isolated with 2 different media, for toxicity testing and the determination of cyanotoxins. Chemical determination of microcystins and other unidentified peptide-like compounds was performed in the laboratory, using high-performance liquid chromatography coupled to diode array detection (HPLC-DAD). The toxicity of the cyanobacteria strains and field samples was determined using a *Thamnocephalus platyurus* bioassay (Okello 2004).

To determine whether or not improvements in water-related disease prevalence have occurred or not, weekly malarial and waterborne disease cases data from the

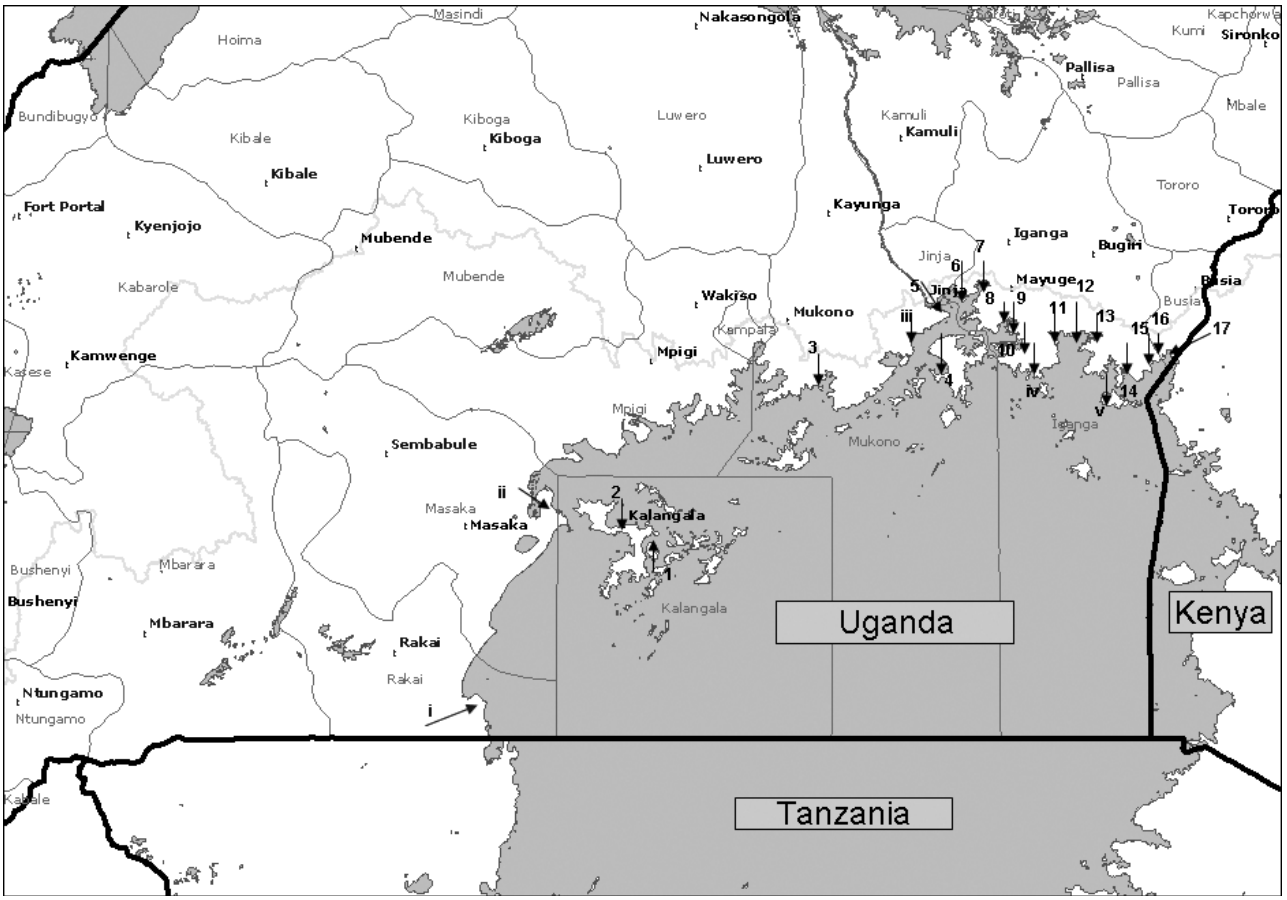

Fig. 2. Riparian districts in which studies were conducted (stretching from Rakai near Tanzanian border to Busia at the Kenyan Border). Numbered arrows in Roman represent the following landing sites: (i) Kasensero; (ii) Dimo; (iii) Kiyindi; (iv) Bwondha; (v) Dorwe. Arabic numerals represent: (1) Lutoboka; (2) Mwena; (3) Katosi; (4) Walwanda; (5) Masese; (6) Wanyange; (7) Wairaka; (8) Lwanika; (9) Bukoba; (10) Kityerera; (11) Bugoto; (12) Wakawaka; (13) Namatu; (14) Lugala; (15) Nalwoba; (16) Majanji; (17) Madua.

Ugandan Ministry of Health (MoH 2009) was collected from July 2008 to January 2009, and analysed and compared with previously collected data from this study.

RESULTS

This study found that the inhabitants at all the landing sites were generally migrants from different areas of Uganda, as well as from other countries in the region. The inhabitants of most lakeshore communities only had primary-level education. The lakeshore soil texture is basically sandy and in some places rocky, making it very difficult and expensive for the local community to construct proper pit latrines, with the estimation being that only half the population had access to proper latrines (LVEMP 2005).

The findings from the October 2002 rapid survey indicated that the prevalent diseases in the riparian communities utilizing the first five landing sites were basically water-related, including malaria, dysentery, diarrhoea, skin-related infections/irritations and influenza. Cholera appeared to be endemic for most of the landing site areas. At the current time, however, cholera has only been reported the Kampala district. Recent studies indicate that the lake is the main water source for the lakeshore communities. Water for domestic purposes is taken from ≈1–5 m from the shoreline. Domestic animals in the community also directly drink water from the same source. All the drainages in the settlements, towns and cities carry stormwater and waterborne waste to the lake. The different sampling sites also displayed differing microbial indicator levels. The total coliforms (TC) were generally very high for all sampling sites, indicating that the water was highly contaminated (Table 1).

There is high variability for coliform counts between the wet and dry seasons. Other studies reported that wet seasons have significantly higher coliform counts than dry seasons for all lakeshore sites (Muyodi 2000; Muyodi *et al.* 2003).

The Lake Victoria Environment Management Project (LVEMP) included construction of latrines, Ecosan toilets and boreholes in some districts, and the success of these facilities has varied throughout the basin. Some constructed boreholes, for example, are not being used because the water contained in them is either salty, or coloured because it contains a high iron content. Further, use of the constructed Ecosan toilets is estimated to be <50% (LVEMP 2005). In fact, the LVEMP noted that the perception and use of Ecosan toilets by riparian communities was generally negative.

Of the 271 respondents from the 17 landing sites screened for *S. mansoni,* 140 were found to be infected, translating into a 51.6% prevalence rate. Water collection from the lakeshore is performed principally by women (64%), making them more vulnerable to the disease than men.

The lowest prevalence of bilharzia (schistosomiasis) is on the southwestern shoreline of the Ugandan portion of Lake Victoria (Fig. 3), close to the Tanzanian border, although the disease prevalence increases eastward as one moves towards the Kenyan border.

The trend in cases of cholera, dysentery and typhoid fever in the riparian districts for the first 13 weeks, which reflects both the dry and rainy seasons (LVEMP 2005) of 2003, 2004 and 2005 is shown in Figure 4. LVEMP (2005) rainfall records, indicates two wet seasons (from March to May and October to December) with maximum rainfall recorded from April to November (Fig. 4). The driest months occurred from July to August, and January to February. Cholera cases were highest in Kampala for the 3 years of record. However, cases of dysentery were high in most districts, being highest in Wakiso, followed by Kalangala.

The mean monthly cholera, dysentery and typhoid fever cases from July 2008, to January 2009 are summarized in Figure 5. Consistent with the findings illustrated in Figure 4, cholera was recorded only in Kampala, whereas dysentery was recorded in all districts.

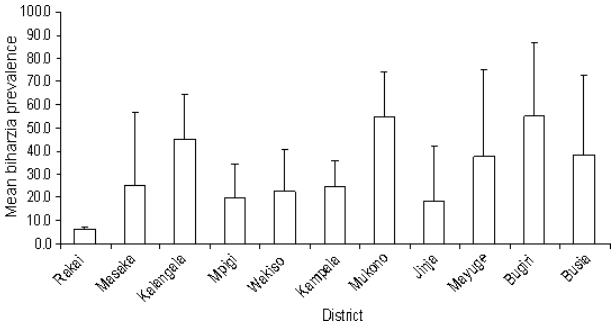

Fig. 3. Prevalence of schistosomiasis in the lake districts in Uganda.

The MoH (2005) reported that malaria represents the major share of the disease burden in Uganda. Governmental and non-governmental organization health facilities have reported an increasing trend in malarial cases, from 5 million in 1997, to 16.5 million cases in 2003 (MoH 2005). The mean monthly malarial cases for the period from July 2008 to January 2009 are illustrated in Table 2.

UNICEF-IRC (2002) reports that the Kampala, Masaka, Jinja and Rakai districts had >500 AIDS cases per 100 000 residents. In Rakai and Masaka, where the epidemic was first reported, HIV prevalence ranged between 10 and 13% (MoH 2003). Other common sexually transmitted diseases (STDs) were sores in the genital parts, gonorrhoea and syphilis.

With regard to Lake Victoria, a total of 13 cyanobacteria species were observed (Okello 2004). Algal blooms were thicker and more frequent in Murchison Bay than Napoleon gulf. Highly toxic blue-green algal scums

Table 1. Comparison of water sources for total iron and coliforms for selected sampling points (under WHO guidelines, *Escherichia coli* must not be detectable in any 100 mL of drinking water)

Sampling site/source	Total iron concentration (g L^{-1})	Total coliform (counts per 100 mL)	Faecal coliform (counts per 100 mL)
Kasensero lakeshore	1.35	2419	1261
Kasensero borehole	39.2	110	0
Dimo lakeshore	0.12	8164	238
Dimo (alternative)	NA	NA	NA
Bwondha lakeshore	0.31	11 198	178
Bwondha shallow well	0.52	2247	3
Dorwe lakeshore	0.4	772	175
Dorwe borehole	1.35	400	10
Kiyindi lakeshore	0.46	20 050	2880
Kiyindi shallow well	0.32	1500	0

NA, not determined.

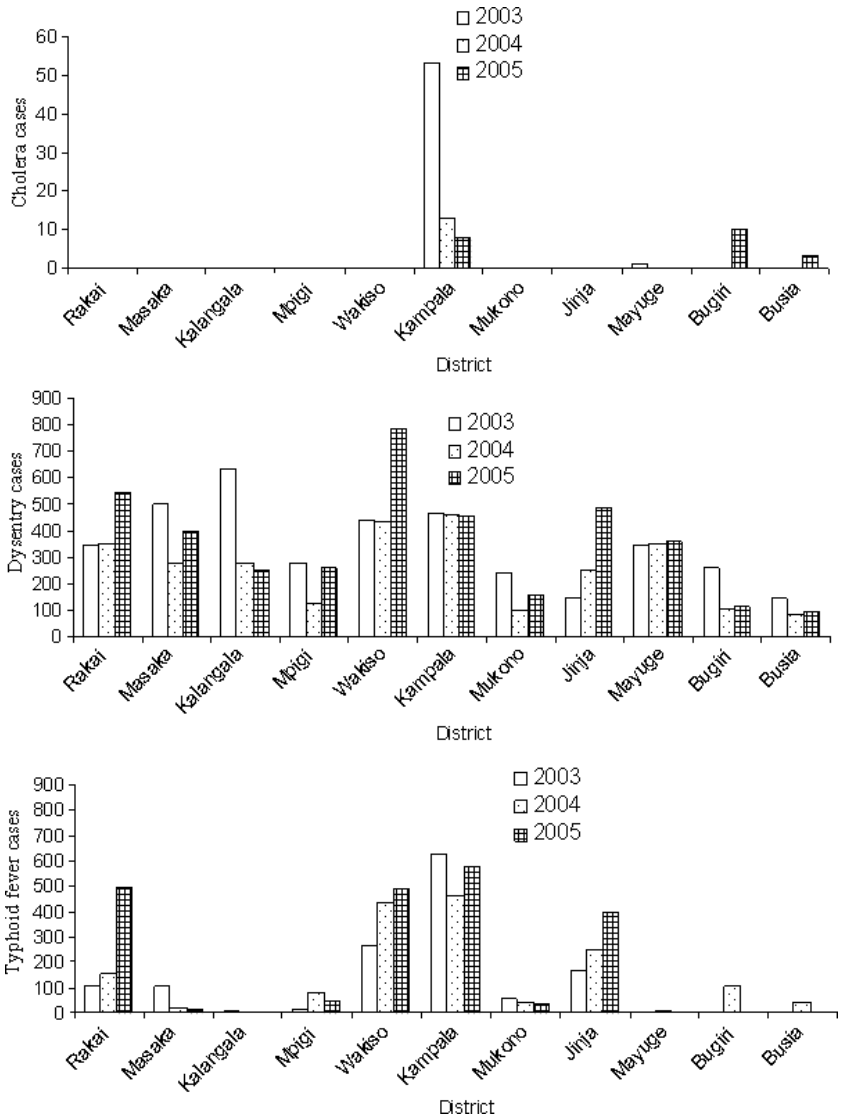

Fig. 4. Trends in waterborne diseases in selected districts in the Uganda area of Lake Victoria catchment (totals for the first half of the years 2003, 2004 and 2005).

(*Microcystis* and *Anabaena* spp.) and water hyacinth (*Eichhornia crassipes*) congregated along the shores of the city of Gaba (Uganda) water intake sites. Based on microcystin test kit results, the algal concentrations were <0.5 μg L^{-1} for nearly all samples. The exception was one sampling site in the Napoleon Gulf, which exhibited a microcystin level of 0.5 μg L^{-1}. For inner Murchison Bay, some water samples exhibited microcystin toxin levels ranging from 0.5 to 3 μg L^{-1}. Studies conducted by the CIDA (2002) indicated that the National Water and Sewerage Corporation (NWSC) water treatment facilities at Gaba II were adequate for removing cyanobacteria from their intake water. It is not known, however, whether or not the NWSC treatment plant is also capable of removing microcystin and other related chemicals from the intake water.

DISCUSSION

High immigration to the landing sites in the Ugandan area of Lake Victoria basin is partly because of a high population growth rate in the riparian districts, in turn resulting in decreasing available land for farming. This factor has resulted in many people pursuing alternative livelihoods such as fishing, which is open access, as well as fishing-related activities. Populations of fishers also tend to travel more widely throughout the Lake Victoria region. Further, many immigrants are from war-affected areas of north and northeast Uganda, whereas some are refugees from neighbouring countries (e.g. Rwanda, Democratic Republic of Congo and Sudan). Population instability makes the dissemination of information more difficult, and disease transmission more likely. This situation also concentrates populations, creasing problems

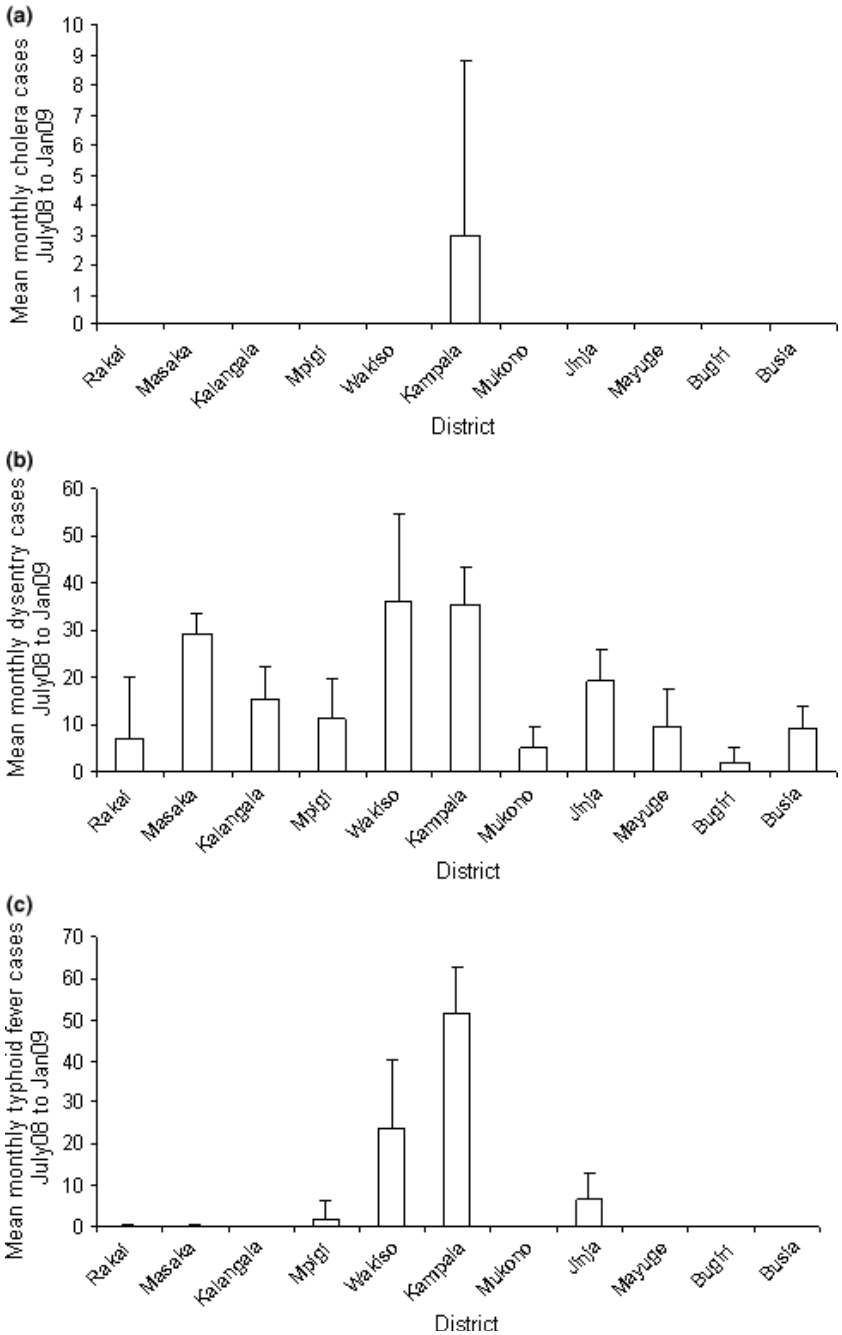

Fig. 5. Trends in waterborne diseases in selected districts in the Uganda area of Lake Victoria catchment, from July 2008 to January 2009: (a) cholera, (b) dysentery and (c) typhoid fever.

with regard to local infrastructures that become overwhelmed, further negatively aggravating local conditions.

The increased run-off of surface water during the wet season mobilizes faecal materials deposited around lakeshore bushes into watercourses and the lake. Thus, seasonal variations in coliform counts correlate positively with the incidences of waterborne diseases, which are higher during the wet season (Muyodi 2000; Muyodi *et al.* 2003, 2005; LVEMP 2005).

The low usage of Ecosan toilets is attributed to several factors. In fishing villages, for example, people are either too poor, or are reluctant, to pay 100 Uganda shillings per visit to the toilets. Sociocultural beliefs also discourage their use. As an example, some cultures believe a young woman will not conceive if she uses a pit latrine, whereas other religious beliefs simply do not accept use of ecosans (LVEMP 2005; Muyodi *et al.* 2005). Thus, many people in the catchment areas dispose of their wastes in bushes, or in polythene bags which they subsequently discard as litter, thereby contaminating water sources with faecal material that, in turn, leads to waterborne diseases.

Table 2. Mean monthly malarial cases in Ugandan Lake Victoria riparian districts, from July 2008 to January 2009

District	July 2008 (mean ± SD; *n* = 1)	August 2008 (mean ± SD; *n* = 5)	September 2008 (mean ± SD; *n* = 4)	October 2008 (mean ± SD; *n* = 4)	November 2008 (mean ± SD; *n* = 4)	December 2008 (mean ± SD; *n* = 4)	January 2009 (mean ± SD; *n* = 5)
Rakai	4279 ± 0	5261 ± 562	4341 ± 710	4974 ± 1166	5025 ± 719	5399 ± 1400	4874 ± 1225
Masaka	5921	5925 ± 22	5871 ± 508	5357 ± 364	5983 ± 378	6190 ± 157	5671 ± 396
Kalangala	795	688 ± 39	688 ± 66	599 ± 83	567 ± 47	556 ± 4	627 ± 29
Mpigi	2498	2218 ± 536	2420 ± 638	3588 ± 729	3674 ± 740	3627 ± 9	4126 ± 552
Wakiso	10 987	9317 ± 421	10 165 ± 1067	11 157 ± 1215	12 561 ± 1091	10 508 ± 1388	10 066 ± 1122
Kampala	7842	10 108 ± 2076	9169 ± 1168	8069 ± 641	9009 ± 840	8743 ± 660	9098 ± 358
Mukono	1909	1949 ± 270	1997 ± 10	2182 ± 190	2284 ± 197	2348 ± 203	2337 ± 143
Jinja	6296	5613 ± 531	4582 ± 160	4710 ± 547	5289 ± 1093	5184 ± 853	3254 ± 691
Mayuge	3115	3440 ± 679	3070 ± 348	3539 ± 613	2361 ± 72	2280 ± 5	2447 ± 171
Bugiri	2640	2103 ± 307	2358 ± 31	2759 ± 531	2449 ± 775	2577 ± 109	2061 ± 61
Busia	3522	2992 ± 431	2267 ± 119	2704 ± 389	3210 ± 470	2975 ± 567	3341 ± 124

SD, standard deviation; *n*, number of sampling counts.

The vulnerability of fisher folk to schistosomiasis was further aggravated by their inaccessibility to both health facilities and health personnel. The nearest health centres were located at distances >1 km away from most of the population. Extension services by health workers also were unsatisfactory. These findings suggest lake water quality was deteriorating as a result of eutrophication (Hecky 1993), a water quality-degrading process that also supports the growth of the intermediate snail host for schistosomiasis. The Ugandan Government launched a campaign against schistosomiasis in March 2003, with ≈500 000 people having received treatment by 2005 (Schistosomiasis Control Initiative 2005).

Kabatereine *et al.* (2004) reported that the prevalence of bilharzia was generally <20% in southwest Uganda not located directly on the Lake Victoria shoreline, whereas it was >50% for the population living closer to the lake. The prevalence of bilharzia decreased with increasing distance from Lake Victoria. *Schistosoma mansoni* infections were found in children as young as 9 months old (Schistosomiasis Control Initiative 2005). Nevertheless, there was a significant difference in bilharzia prevalence between those who regularly used latrines and those who did not. This is attributed to the fact that parasitic eggs of *S. mansoni* released directly into the environment from infected individuals rupture on contact with fresh water to release the free-swimming miracidium larvae (Tukahebwa 2001). An increased incidence in bilharzia was observed from the southwest towards the eastern shoreline of Lake Victoria (Kabatereine *et al.* 2004).

Kabatereine *et al.* (2004) also reported that, for areas located >1324 m a.s.l., little or no transmission of bilharzia was observed. The same was true for areas receiving annual total rainfall of <900 mm. No relationship was demonstrated between infection patterns and temperature- or vegetation-derived variables. Rather, poor health facilities and practices at most landing sites might be contributing to the observed high prevalence of bilharzia. The overall prevalence of bilharzia in schoolchildren (overall prevalence of 20.4%) was lower than that observed for landing site communities (overall prevalence of 47.5%) wherein fisher communities are constantly in contact with the lakeshore as they strive to earn their livelihoods.

Current malaria prevention efforts in Uganda include controlling the breeding grounds of the mosquito vectors, use of insecticide-treated mosquito nets and anti-malarial drugs (especially for expectant mothers). The MoH is also considering the use of dichloro-diphenyl-trichloroethane (DDT) as an indoor residual spray to kill the vector mosquitoes. DDT was initially introduced to control vector-borne diseases, including malaria. However, its use was banned in the United States in 1972 because of its potential harmful effects on humans, wildlife and the environment (Jaga & Dharmani 2003). Thus, the use of DDT to control malaria must be carefully studied before its application, including consideration of the fact that mosquitoes might acquire resistance to it over time, and it also is a non-specific pesticide, thereby capable of also killing many non-target organisms. Minakawa *et al.* (2008) recently reported that recent decreases in the water level of Lake Victoria has increased the total area of the available habitat for *A. funestus,* one of the mosquito vectors for malarial parasites. Their results suggest

that the lake's decreased water level has substantially affected the population of this malarial vector in the Lake Victoria basin, particularly in view of the fact that the lake has a long shoreline that can harbour many new breeding habitats. In addition to its human health impacts, malaria also has a great impact on the economic prospects of individuals, their families, lakeshore communities and the nation as a whole, related mainly to the need for repetitive treatments, increasing treatment costs and increasing prevention costs (MoH 2005).

The selling of alcohol is an income-generating strategy being adopted by women in Uganda. It also is associated, however, with risky sexual behaviour. An alcohol consumption-centred lifestyle frequently is observed around most landing sites. This situation is aggravated by a highly mobile population, and high rates of immigration. Accordingly, AIDS and STDs are common at the landing sites, being attributed to a high rate of prostitution, little attention paid to 'safe sex' and the prevalence of HIV-infected migrant persons. The large number of AIDS cases in Kampala and Jinja is attributed to the high concentration of urban residents, whereas it is mainly because of the early onset of HIV/AIDS in those districts in which it was first identified (Masaka and Rakai).

Cyanobacteria were dominant at most sampling sites, extending to deeper eutrophic areas of the lake (Kling *et al.* 2001; Okello 2004). The observed microcystin levels were higher than the 1.0 $\mu g\ L^{-1}$ WHO guideline for drinking water in the inner Murchison Bay (CIDA 2002). Neither the age nor the stage of a particular cyanobacterial bloom was determined in this study. It appears the cyanobacteria cells had not yet lysed, thereby still containing the toxins within its cells. There is a possibility that cyanobacteria comprising older, deteriorating blooms might rupture, releasing toxins, both before or during water treatment. This situation would expose Kampala residents to moderate microcystin levels in their drinking water. Further research is required to establish the risks to riparian populations from these cyanobacteria, noting there currently is not any specific health screening in place to establish the potential human health impacts of exposure to the neurotoxins and hepatotoxins of cyanobacterial origin. Current sanitary practices of shoreline communities are contributing to degradation of the nearshore areas of Lake Victoria. The communities also are suffering the consequences of the degradation they are causing. Recent environmental changes in Lake Victoria (including its long-term eutrophication, which has resulted in nearly continuous cyanobacteria blooms in its coastal areas; Kling *et al.* 2001) also are increasing the human health risks to the populations living along the lakeshore. At the same time, the rapid growth of the lake's fishery after 1980 (Kolding *et al.* 2008) has caused a massive migration to the lakeshore by residents and migrants seeking better livelihoods in this rapidly expanding economic sector. The two factors combined have caused a rapid deterioration in the health status of the riparian populations, however, challenging the capacity of government authorities to address these issues.

CONCLUSIONS

Malaria continues to be the most prevalent water-related disease, followed by dysentery, in the Lake Victoria riparian districts of Uganda. The lowest prevalence of malaria and bilharzia is on the southwestern shoreline, close to the Tanzanian boarder, increases as one moves eastward along Lake Victoria to the Kenyan border. Dysentery is the most common waterborne disease, followed by typhoid fever and cholera, respectively. In the order of seriousness, the most affected districts are Kampala, Wakiso, Jinja and Kalangala. AIDS and STDs were common at the landing sites, mainly because of high rates of prostitution, lack of concern regarding 'safe sex' and the presence of large numbers of HIV-infected migrants. A high population mobility, and high rates of immigration to landing sites, contributed to the observed high prevalence of HIV/AIDS and STDs. Overall, ≈17% of the Uganda's population has no access to toilets or latrines. Only 55 and 62% of the rural and urban populations, respectively, had access to clean, safe drinking water (Uganda Bureau of Statistics (UBOS) 2005). Further, some riparian districts have low water and sanitation coverage. The Rakai district water coverage, for example, is only 42.6%. Highly toxic blue-green algal scum tends to accumulate along the shore of Gaba water intake sites, with observed microcystin levels being higher than the WHO guideline, thereby posing a threat to both human and animal health. Water treatment for serviced communities could lower the health risks. For unserviced communities, or those taking water directly from the lake, however, algal toxins pose a greatly increased risk, particularly as eutrophic conditions can result in algal blooms dominated by toxic cyanobacteria.

RECOMMENDATIONS

It is clear from this and other studies that increased efforts should be directed to reducing waterborne and water-related diseases in the Uganda area in the Lake Victoria basin. Such efforts would contribute considerably towards improved health and standard of living for the lake riparian communities. The main focus should be increased health education and sensitization to waterborne diseases and their causes, combined with improved

sanitary structures. The goal of improved quality of domestic water supply in a number of selected locations also should be included in such programmes. Low cost, locally initiated infrastructure development (latrines, small water supplies, etc.) should be a starting and focal point. These activities should primarily encourage changing the hygiene and behavioural habits of people, and should be based on a long-term approach, as changing the minds of large numbers of people is neither a simple nor rapid task. The use of cheap, sustainable, home-based methods of purifying or treating water also should be explored. An example is the potential use of plants such as Moringa (*Moringa oleifera* Lam) as a flocculating agent, as well as simple sand and fine-grained filtering systems. Simple water disinfection at the household level, using ultraviolet light, also could be considered. Compulsory Universal Primary Education for all school-age children living in shore and near-shore settlements also must be ensured as a means of improving the literacy level which, in turn, should result in improved hygienic and sanitary practices. Finally, exposure to algal toxins is an increasingly important, but understudied, risk factor for the health of lakeshore populations. Further study is needed to better understand and define the risks of, and solutions to, cultural eutrophication that is the basic cause of the dominance of toxin-producing cyanobacteria.

ACKNOWLEDGEMENTS

Special thanks are due to Thomas Ballatore for his extensive review of the manuscript and his assistance in generating the study map. This research was funded in part by the Lake Victoria Environmental Management Project (LVEMP), with contributions from other projects in the lake basin. The assistance of the staff of the Directorate of Water Resources Management (Ministry of Water and Environment), Fisheries Research Institute, National Water and Sewerage Cooperation and the Department of Zoology, Makerere University, where the actual studies were performed, is gratefully acknowledged. The Canadian International Development Agency (CIDA) provided valuable support through its International Youth Internship Programme. Thanks are also due to the Ministry of Health for secondary data on the prevalence of water-related diseases.

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