CHAPTER 11
Water quality and health conditions in Lake Victoria region, Uganda

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ABSTRACT. *The prevalence of water-related diseases and associated health risks in the Lake Victoria region of Uganda is discussed. The aim of the study was to examine the trend of the diseases and health risks in the riparian communities and suggest intervention measures. Surveillance studies were carried out by the Water Resources Management Department, Directorate of Water Development and the Fisheries Resources Research Institute (FIRRI). Other sources of data included review and analysis of findings from different studies in the region and the Ministry of Health (Uganda). Fecal coliform counts in water samples were analyzed for indication of faecal contamination. The coliforms were generally very high in most of the sampling sites indicating that the waters were highly contaminated. The riparian communities source their water for domestic consumption mainly from the lake. The wet seasons had significantly higher coliform counts than the dry seasons for all lakeshore sites. This seasonal variation in coliform counts correlates positively with waterborne disease incidences that are higher in the wet season.*

The most prevalent diseases in the landing sites included malaria, dysentery, diarrhea and bilharzia. Cases of cholera, skin-related infections and influenza, where also observed. Malaria continues to be the most prevalent water related disease for Uganda followed by dysentery in the riparian districts. Prevalence of bilharzia caused by Schistosoma mansoni was also found to be significantly high in the riparian districts. Fisher folk vulnerability to water-related diseases was further aggravated by inaccessibility to both health facilities and personnel. There was a significant difference in bilharzia prevalence between those who used latrines regularly and those who did not.

Other health risks in the riparian communities arise from frequent algal blooms in Lake Victoria. In Lake Victoria, cyanobacteria dominate other algal species and contribute a larger fraction (>50%) of the biomass. Cyanobacteria are potentially toxic to humans and animals and impair the ecological and aesthetic values of lakes. Algal blooms also cause unpleasant odours and tastes in domestic water supplies, clog filters on pumps and machinery, increase chlorine demand, requiring a more complex and expensive treatment process. Thick algal blooms were found to be frequent in Murchison Bay, a source of drinking water for Kampala and the surrounding urban centers.

The use of Ecosan toilets constructed by LVEMP in the riparian communities was estimated to be less than 50% on average because of user fee and socio-cultural factors hence many people in the catchment disposed their wastes in bushes or in polythene bags, contaminating water sources with fecal material and leading to waterborne diseases. Findings suggest that water quality and sanitation improvements, in association with hygiene behaviour change can have significant effects on population and health by reducing a variety of waterborne and water-related diseases.

Key words: bilharzia, cyanobacteria, diarrhea, dysentery, Lake Victoria, malaria, Uganda.

INTRODUCTION

Like many developing nations, Uganda faces a high population density accompanied by a relatively poor infrastructure. In the urban centers and some rural settlements, the available sanitary facilities cannot sustain the population, leading to contamination of surface water sources with fecal material. As a result, waterborne diseases such as cholera and typhoid fever have become rampant (Byamukama *et al*. 2005a). The low latrine coverage that leads to pollution of water sources, and cultural practices especially during burial ceremonies compounds the problem (WHO 2001).

Waterborne Biological Contamination

Biological contamination of water takes place when human and other warm-blooded animal faecal material finds its way into water bodies. This waterborne biological pollution, frequently referred to as faecal pollution on top of introducing bacteria of faecal origin into the water body also accelerates eutrophication of a water body which causes explosive growth of algal species (Muthoka *et al*. 1998).

Bacteriological Contamination

The gut of warm blooded animals is home to a group of bacteria referred to as the enterobacteriacea. Some members of the enterobacteriacea, the coliforms, are harmless whereas others are pathogenic and may be the cause of waterborne diseases. The presence of coliforms in a water body is therefore an indication of faecal pollution and deteriorates the quality of water. Presence of faecal coliforms specifically is an indication of recent faecal contamination of the water source and implies a high risk of contracting water borne diseases if the water is used for drinking purposes without treatment (Odada *et al*. 2004). Under the WHO guidelines, *E. coli* must not be detectable in any 100 millilitre (ml) sample of drinking water. For treated water entering, or in the distribution system the same recommendation is also given for total coliform bacteria, with a provision for up to 5% positive samples within the distribution system. The rationale for this additional criterion is the greater sensitivity of total coliforms for detecting irregularities (not necessarily faecal contamination) in treatment and distribution (Havelaar *et al.* 2001).

The use of indicator bacteria such as fecal coliforms (FC) and *Escherichia coli* for the assessment of fecal pollution and possible water quality deterioration in various fresh water sources is a widely used and accepted concept in temperate regions (Toranzos and McFeters 1997; APHA 1998). Coliform bacteria have been found in waters of turbidity between 4 and 84 NTU. In turbid water, *Escherichia coli* has been shown not to be destroyed in the presence of high levels of chlorine from 0.35 mg/litre and above. The consumption of highly turbid water may constitute a health risk, as turbidity can protect pathogenic microorganisms from the effects of disinfectants (LVEMP 2004). Therefore increases in turbidity and suspended materials in surface waters are undesirable, but such increases have been widespread with land clearance for agriculture and too little attention to soil erosion.

Water quality therefore has an impact on human health. Other factors contribute significantly to human health and these are, in a simplified model: the sanitation / waste disposal practices in the communities, health education undertaken to change people’s attitudes and practices related to the use of water and sanitary facilities. These three factors are closely inter-related and each one influences the other, as illustrated in Figure 1.

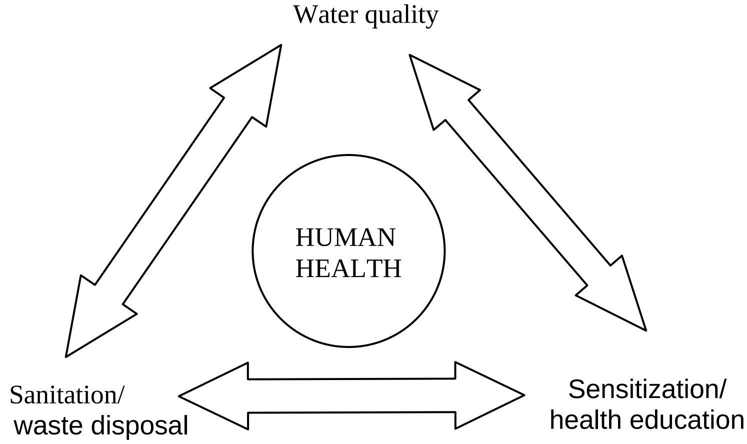

FIG. 1. The relationship between water quality, sanitation, health education and human health.

It is very difficult in most cases where these three factors prevail, to single out the one having the largest impact on human health. This dilemma is also confirmed by all actors in the health sector, and has in fact been known for decades also by water development professionals. These inter-relations were much focused on during the International Water Decade in the 1980s. LVEMP phase 1 has focussed attention on current water quality of Lake Victoria, its change from historic baselines and the factors accounting for those changes.

Water quality and sanitation improvements, in association with hygiene behaviour change can have significant effects on population and health by reducing a variety of waterborne and water-related disease. These improvements in health can, in turn, lead to reduced morbidity and mortality and improved standards of living. Water and sanitation improvements affect health primarily by interrupting or reducing the transmission of disease agents (Figure 2).

Of primary importance is the safe disposal of human faeces, thereby reducing the pathogen load in the ambient environment. Improving the quality of drinking water reduces the ingestion of pathogens. Modest improvements in sanitation, such as pit latrines, will result in better health. Increases in the quantity of water for personal use allows for better personal and domestic hygiene practices (Huttly *et al.* 1997). Improvements in water and sanitation do not automatically result in improvements in health. The addition of hygiene education is often required for health impacts to be seen.

The human relation with polluted water along the shores of Lake Victoria is based on the fact that there are basically two relevant sources of water influencing the health of the lakeshore population: the lake water itself and the on-shore drinking water sources in the communities (rivers/streams, wells, boreholes and springs, where such exist). The other sources of water which influence human health, such as floodwater in and around the communities during the rainy season, also used for domestic purposes are significant but temporary. The interactions between large water bodies and human beings having serious health impacts are mainly: swimming/bathing, drinking and eating (poisoned or contaminated fish). The health implications could be many and selections of the presumably most relevant ones are presented in Figure 3.

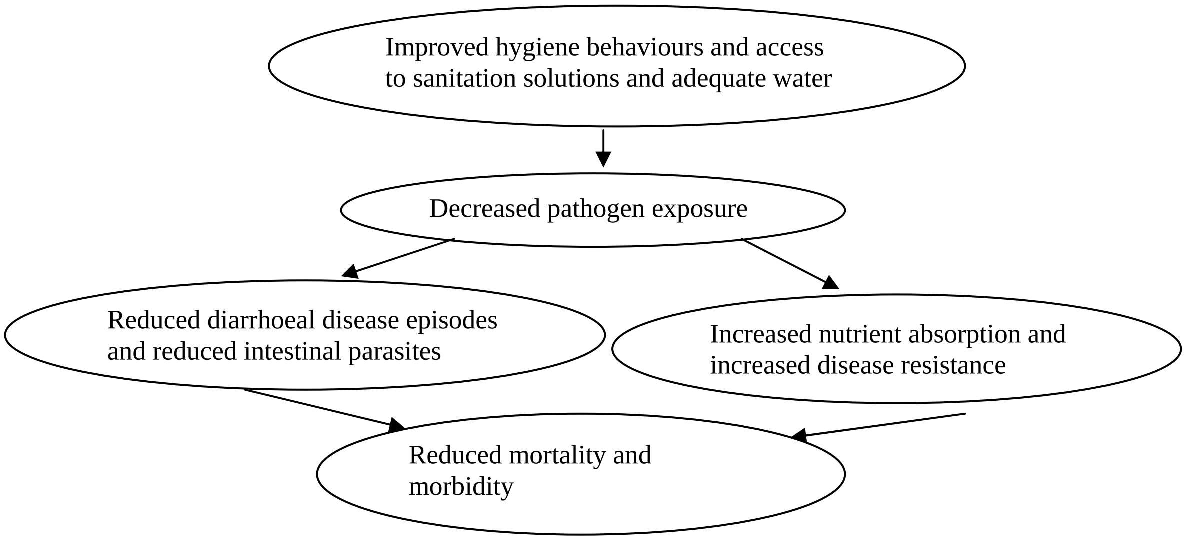

FIG. 2. Water and sanitation in relation to disease transmission.

Figure 3 indicates that domestic hygiene practices and various interactions on developmental activities, physical interaction in the lake (for example, water hyacinth removal) and health education have influence on the health implications. The underlying limiting factor in the water and sanitation sector in the region is however believed to be poverty.

Studies on bacteriological contamination of Lake Victoria shores

LVEMP I Studies

In October 2002, the LVEMP staff undertook a rapid survey of five landing sites, with water sampling and review of diseases from the nearest health centres. The study was intended to analyze the disease prevalence and sanitary conditions at selected landing sites. The landing sites studied were Kiyindi (Mukono District), Kasensero (Rakai District), Dimo (Masaka District), Bwondha (Mayuge District) and Dorwe (Bugiri District).

The study targeted local officials as key informants at the landing sites and health workers of the most frequently visited health centers in the communities. An interview guide 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 observations were used for data collection to verify responses from respondents on hygiene and sanitation, the water characteristics and waste disposal facilities. Water samples were collected from the available water sources and analyzed for physical, chemical and pollution indicator microorganisms (APHA 1998). Water sources, which varied from site to site, included the lakeshore, springs, shallow and deep wells (where they existed).

Findings indicated that generally the inhabitants on all the five (5) landing sites were mainly migrants from different areas of Uganda, and immigrants from the region hence suggesting heterogeneous cultures. High immigration to the landing sites is partly due to a high population growth rate in the riparian districts, resulting into less and less available land in the main land for farming, forcing many people to look for alternative livelihoods such as fishing and related activities. Many of the immigrants are also from war affected areas of Uganda (north and north east), while some are refugees from neighboring countries (Rwanda, Democratic Republic of Congo and Sudan). The education level for most of the lakeshore communities was primary level. The households are basically semi-permanent structures of wood and iron sheets that have been constructed near the shoreline. Trees and bushes surround the landing sites. The soils are basically sandy and frequent foot trampling form paths naturally which can become small water courses during rains.

The main prevalent diseases in these communities were basically water-related. They included malaria, dysentery, diarrhea, skin-related infections and influenza. Cholera seems to be endemic in most of the landing sites. Recent studies show that lake water is still the main source of water for the communities. Water is drawn from about 1 to 2 meters from the shoreline. It is used for cooking, washing and other domestic purposes. Domestic animals owned by members of the community also directly drink water from the same source. All the drainages in the settlement carry storm water and waste-washed water into the lake.

Electrical conductivity is the ability of an aqueous solution (water for example) to carry an electric current and it depends on the presence of ions, their total concentrations and the temperature at the time of measurement. The most abundant ions in aquatic habitats are sodium (Na^+) and chloride (Cl^-). Faecally contaminated water contains a lot of Na^+ and Cl^- ions from urine. Others include magnesium (Mg^{2+}), calcium ($^{2+}$), and potassium (K^+). Water with very high conductivity is more difficult and expensive to treat for drinking and other domestic purposes. Figure 4 presents the electrical conductivity of samples collected from various water collection points at different landing sites of Lake Victoria. Bwondha shallow wells have higher conductivity values than the shore waters probably due to the geology which facilitates infiltration of ions from the surroundings into these wells. Although wells tend to filter ground water and hence expected to have “cleaner water”, this depends on the wellhead protection in place in contrast to open water of the lake that have no “treatment” such as the well provides. The different sampling sites also displayed various microbial indicator levels. The total coliforms were generally very high for all the samples indicating that the waters were highly contaminated (Figure 5). Bwondha shore has more coliforms than Bwondha well. The faecal coliforms were found to be highest at Kiyindi (Figure 6) indicating a very high bacteriological contamination at the shore. This explains the observed high prevalence of waterborne diseases in the lakeshore communities. Further information on the individual communities is given in the following subsections.

Kasensero landing site

The landing site located in Rakai District has an estimated population of about 7,000 people, mostly immigrants. Population instability makes information dissemination difficult and disease transmission more likely. It concentrates populations and creates problems for local infrastructure that becomes overwhelmed further aggravating the situation (Figure 1). There were 5 privately owned health units and to date, one government-aided Kasensero Health Centre II. Another government aided health center is about 10 Km away from the landing site. The major water source is the lake water. Alternative sources include a shallow well about 3 Km away, 5 non-functional boreholes were also seen. There are inadequate pit-latrines, many residents dispose off their wastes in the nearby bushes (Muyodi *et al.* 2005). There were 3 water borne toilets aided by the District Development Fund and the World Vision. A few landlords provide latrines and about 30 people may share a single latrine. Many people bathe either inside their mud-floor houses, nearby bushes or directly in the lake. All these practices increase risk of disease transmission within the population. The prevalent diseases include malaria, Acquired Immune Deficiency Syndrome (AIDS), dysentery, and other water related diseases.

Dimo landing site

Dimo landing site has a population of about 3000 people. Households consist of semi permanent structures built using bricks and roofed with iron sheets. The community has 5 privately owned clinics operated by nurses. The nearby government aided hospital; Kalisizo, is 30 kilometers away from the landing site. The major diseases included malaria, diarrhea, dysentery and worm infections, and were more prevalent in children.

Sanitary facilities were very poor. These included insufficient pit latrines and the household garbage was piled in nearby bushes or behind the households for long periods before incineration. The community had 2 public latrines provided under the LVEMP and World Vision, an international non-governmental organization (NGO). One hundred Uganda shillings is charged per visit, seen to be on the higher side for most of the fisher communities to afford. There were also four privately owned latrines built of wood and mud. Landlords provided these pit latrines, and each was shared by about 5 households. Those who did not have latrines and could not afford to pay the user fee used nearby bushes to deposit faecal material. The main water source is the lake. This water is not good for direct human consumption as streams wash wastes and runoffs into the lakeshores. Domestic animals drink from the same source.

Bwondha landing site

The site has a population of about 10000 people, consisting of Ugandans and Kenyans. The landing site is surrounded by bush vegetation. Semi permanent structures made up of wood, roofed with iron sheets, used as houses, are built near the shoreline. The community has one government-aided dispensary, Bwondha dispensary, supervised by a nurse and 8 privately owned health units.

The most common diseases were malaria, diarrhea, dysentery, worm infestations and skin diseases. The main water source is the lake, and many households do not boil water before consumption. The community had no public pit latrine, and the majority of the people use the bushes to deposit fecal material, which is washed by runoff into the lake. The few private latrines available are shared by 4-5 households. Majority of the people wash and bathe in the lake. As a result the community has experienced various incidences of water-related disease outbreaks including cholera, dysentery and diarrhea. AIDS and STDs were also common, the underlying factor being prostitution and unsafe sex.

Household garbage is dumped in public garbage sites where it is later incinerated. Other alternative sources of water include one borehole and a commercially available twenty litre container costing 200 Uganda shillings which is very expensive for the majority of the people. There also exist 2 shallow wells. It was noted that the lake coliforms are higher than the well coliforms in Figure 5 demonstrating some improvement over use of contaminated lake water; however, the coliform count is still too high suggesting poor maintenance and protection of the well.

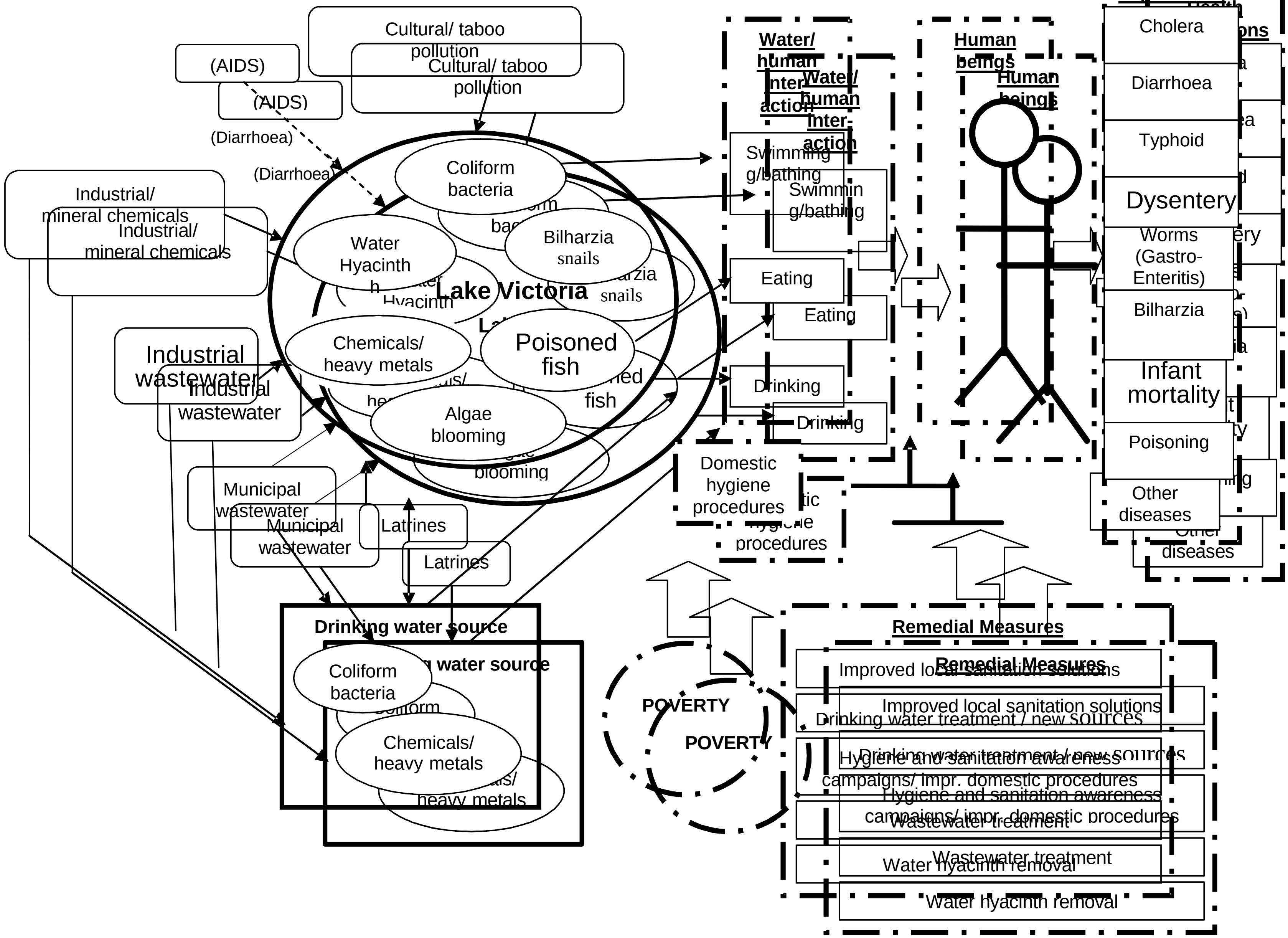

Figure 11.3 Simplified schematic relations between water quality in Lake Victoria (large circle) and human health

Dorwe Landing Site

The landing site is part of Sigulu Island in Bugiri District with a population of about 5000 people and is accessed by water. The site has 10 privately owned clinics, and one government aided health unit, Kandege, situated 3 kilometers away. The most prevalent diseases were diarrhea, skin related infections, malaria and cholera. Other common diseases were STDs and HIV/AIDS. Households dispose off their solid wastes in nearby bushes, which is washed down into the lake by runoff. Alternative sources of water included one shallow well, and borehole located one and half kilometers away from the landing site. There were 3 public latrines, aided by the community action plan and 10 privately owned latrines. The majority of the population did not have latrines.

Kiyindi landing site

This site is located in Mukono district with a population of about 10000 people. The community is largely immigrants from Rwanda, Kenya and migrants from Northern Uganda. There were 7 privately owned health units and a government aided health center. The major diseases reported included malaria, skin diseases, diarrhea and eye infections. Intestinal worm infections, dysentery, STDs and AIDS were also reported (Source: Makonge Health Center, 2002). The lake is the main source of water for the community. A stream / drainage channel from the settlement carries wastes into the lake. The landing site has pit latrines constructed under the district development fund. It is expensive for the local community to construct proper toilets as the soil texture is sandy. It was estimated that only half of the population had access to proper latrines.

The garbage was collected in bins and thereafter incinerated. In addition, oil spills from boat engine repair and car washing drain into the lake. The only significant alternative water source is a well about 1km from the landing site.

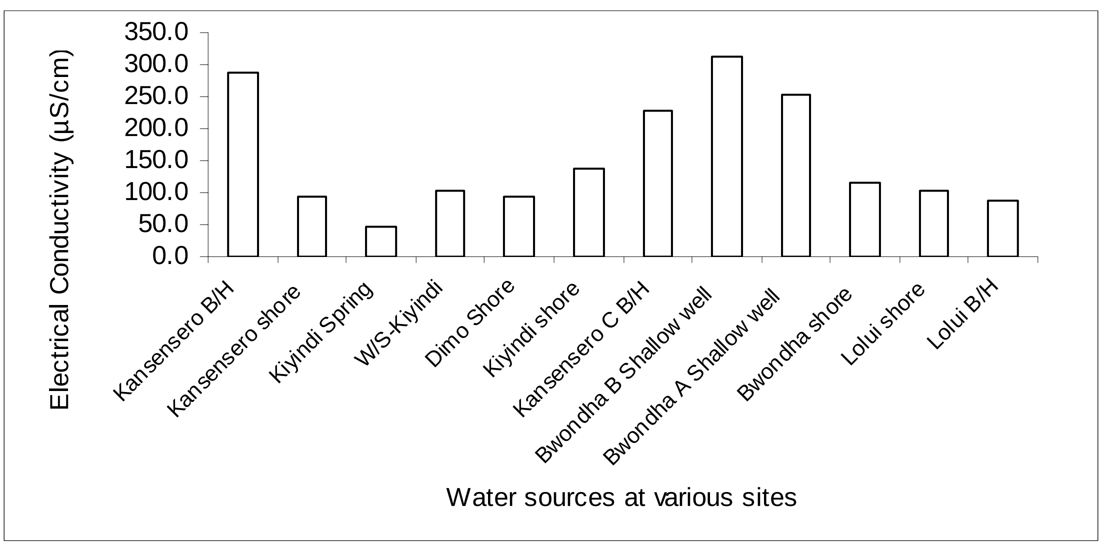

FIG. 4. Electrical Conductivity of water samples from various sources at landing sites of Lake Victoria.

Other Studies

Other microbiological studies have been conducted by LVEMP under National Water and Sewerage Corporation (NWSC) to determine the bacteriological quality of lakeshore waters used by lakeshore communities. Figure 7 presents the faecal coliforms counts in water samples collected from various fishing villages along the shores. The faecal coliform counts are comparable to those presented by the rapid water survey of LVEMP (2002).

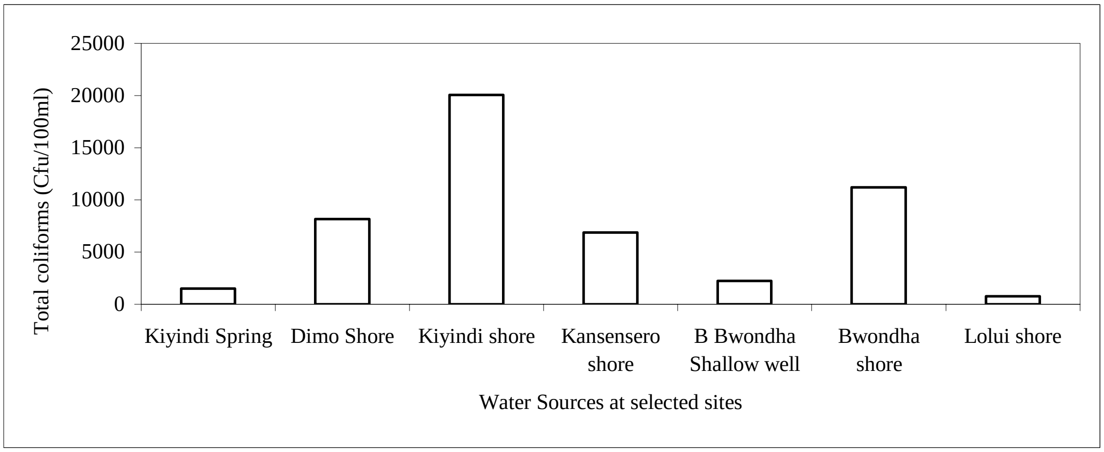

FIG. 5. Total coliforms in water samples from various sources at selected landing sites of Lake Victoria.

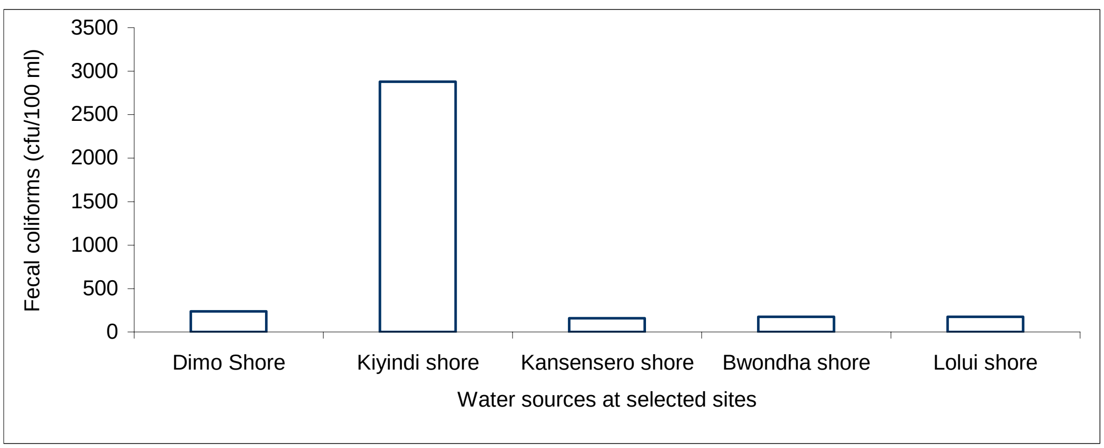

FIG. 6. Fecal coliforms in water samples from various sources at selected landing sites of Lake Victoria.

There is high variability between the seasons for coliform counts between wet and dry seasons. The wet seasons have significantly higher coliform counts than the dry seasons for all lakeshore sites (Muyodi 2000; WHO 2001; Opio 2002; Byamukama *et al*. 2005b; Kansiime *et al.* 2005). The wet season increases runoff of surface waters that mobilizes fecal material into the water courses and into the lake. This seasonal variation in coliform counts correlates positively with waterborne disease incidences which are higher in the wet season.

LVEMP Interventions towards improvement in sanitation and clean water access

LVEMP 1 through the micro projects also aimed at generating food, safe water, employment, incomes and a disease free environment to its riparian communities. Latrines, Ecosan toilets and boreholes were constructed in some districts by LVEMP. The success of these facilities varied from place to place. Some of the boreholes constructed are not being used because the water is either salty or contains a lot of iron. The use of Ecosan toilets is estimated to be less than 50% on average because of several reasons. Ecosan toilets were constructed in Dimo, and Wanyange (Jinja), amongst others. In fishing villages, people are too poor or reluctant to pay UGSH 100 per visit to the toilets. Also, socio-cultural beliefs discouraged the use of the Ecosan toilets. As a result, many people in the catchment dispose their wastes in bushes or in polythene bags, and therefore contaminating water sources with fecal material which in turn leads to waterborne diseases.

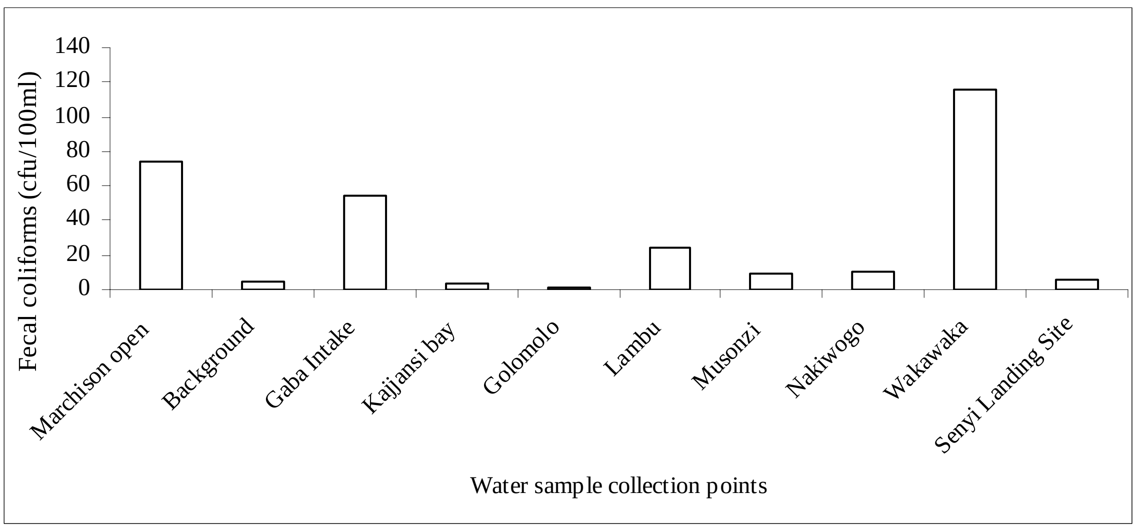

FIG. 7. Faecal coliforms in water samples at various lakeshore villages.

Algal toxins

In Lake Victoria, cyanobacteria dominate other algal species and contribute a larger fraction (>50%) of the biomass (LVEMP 2003). A general pattern of increasing dominance of N-fixing types (*Anabaena* and *Cylindrospermopsis*) in inshore and non-N-fixing types (*Microcystis* and *Aphanocapsa*) in offshore waters was reported by Kling *et al*. (2001) and apparent in qualitative algal examination from the Lake Victoria. This dominance has evolved since the 1960's when cyanobacteria were a minor component of the phytoplankton. Average total algal biomass was approximately 4 times higher in the inshore shallow regions than in offshore. Shallow mixing depths (Mugidde *et al.* 2003) and high nutrients concentration in inshore shallow regions boost the development of algal biomass.

The specific importance of cyanobacteria for water managers arises from their possible toxicity to humans and animals and the ecological and aesthetic consequences of their blooms to individual lake and river systems. Cyanobacteria have been found to poison wild animals such as fish, kangaroos and birds (Krienitz *et al*. 2003). Humans are affected in various ways including skin and eye irritations, diarrhea, disorders of the nervous system, and liver damage.

Cyanobacteria toxins accumulate in the tissues of fish, particularly in the liver and kidney, the level of accumulation depending upon the severity of the bloom in the area where the fish lives. Caution should be taken when considering the consumption of fish caught in areas of a water body where serious blue-green algal blooms occur. The liver and kidney of the fish should in particular not be consumed.

Depending on the part of the body the algal toxins affect, algal toxins can be classified into four different categories: Hepatotoxins affect the liver and other internal organs of the poisoned victim (Muhamed *et al.* 2003). Some have also been identified as cancer promoting substances. Neurotoxins affect the nervous and respiratory systems, and may lead to respiratory failures. The endotoxins are contact irritants, and can cause severe dermatitis and conjunctivitis in people coming into contact with algae through swimming or showering. They may also cause stomach cramps, nausea, fever and headaches if consumed. Their presence in airborne droplets can cause asthma. Some are also thought to be possible tumour promoters, although this has yet to be proven conclusively. Non-specific toxins are relatively slow acting general toxins that progressively damage most organs, including the liver.

Phytoplankton toxins are usually released into water when the cells rupture or die. Scientists world-wide are more concerned about hepatotoxins than neurotoxins, because neurotoxins are not considered to be as wide-spread as hepatotoxins in water supplies. Very few cyanobacterial toxins have actually been isolated and characterized to date and research in this area is expanding rapidly around the world.

The main three toxin producing blue-green algae in the tropics are *Anabaena*, *Microcystis* and *Cylindrospermopsis. Anabaena* and *Microcystis* are the two main bloom-forming genera in tropical waters including Lake Victoria. *Anabaena* forms long chains of cells, called a trichome, which sometimes grows in a spiral, depending on the species. *Microsystis aeruginosa* is most common in lakes and reservoirs. It forms irregularly shaped colonies of cells up to 1 to 2 mm wide that can be visible to the naked eye. *Microsystis* blooms can be quite persistent lasting for months, or even years in some cases. *Cylindrospermopsis* which is very abundant in Lake Victoria is commonly thought of as sub-tropical blue-green algae, but it also occurs in more temperate regions during the summer. It has very tiny cells that form chains or trichomes. It is a freshwater species, and causes problems in town water supply systems due to its highly potent toxins.

Algal blooms present expensive problems in the water industries because they cause unpleasant odours and tastes in domestic water supplies, clog filters on pumps and machinery, increase chlorine demand, leading to increased trihalomethane (THM) precursors which lead to increased chloroform and other potential carcinogens in treated water supplies and increase costs of operating water treatment plants. Many conventional water treatment works can remove algae, but they cannot usually remove the toxins, released from burst or dying cells, produced by some blue-green algae; that requires a more complex and expensive treatment process.

Studies on toxic cyanobacteria in Lake Victoria, Uganda

A few studies to characterize toxic cyanobacteria in Lake Victoria have been conducted (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. Sampling sites on Lake Victoria were Murchison Bay, Napoleon Gulf and Jinja wetland finger ponds. Samples were either collected from 1m depth or integrated with a 2 litre horizontal Van Dorn sampler. Net samples were taken by vertical-net hauls using plankton nets with 30 µm-mesh size. Species determination was done microscopically, and 192 strains were isolated using 2 different media, for toxicity testing and the determination of cyanotoxins. The chemical determination of microcystins and other unidentified peptide-like compounds was done in the laboratory using high performance liquid chromatography coupled to diode array detection (HPLC-DAD). Toxicity of strains and field samples was determined using *Thamnocephalus platyurus* bioassay (Okello 2004).

In total, 13 cyanobacteria were found. Cyanobacteria were dominant at sites which were deeper and eutrophic for Lake Victoria. All cultured strains were found to contain unidentified peptide-like compounds and cyano-peptide compounds were present at all field sampling sites. The majority of the cultures and field samples showed high toxicity to *Thamnocephalus* within 24 hours. There was a mismatch between microcystin occurrence and the toxicity to *Thamnocephalus* observed implying the production of so far unidentified toxic compounds in Ugandan freshwater habitats (Okello 2004).

Another study to monitor cyanobacteria in Lake Victoria was conducted by the Canadian International Development Agency (CIDA), in collaboration with Fisheries Resources Research Institute (FIRRI) and later with the National Water and Sewage Corporation (NWSC), Kampala. Samples were collected from the Napoleon Gulf, Jinja, near FIRRI laboratory as well as the source for drinking and domestic water used by the Jinja population (CIDA 2002). Other samples were collected at the inner Murchison Bay. Inner Murchison Bay was selected as it is the source of two water intake points (Gaba I and Gaba II) operated by NWSC. Murchison Bay is well known for its frequent algal blooms as well as patches of water hyacinth that can modify algal bloom abundance.

Samples were collected using a Van Dorn water sampler, preserved using Lugol's solution, and taken for phytoplankton identification in the laboratory. In the laboratory, water samples were frozen to rapture the algal cells and release endo-toxins into the water samples. Samples were also observed under an inverted microscope and microcystin analysis done using Envirologix microcystin tube kit-ET 022 (Maine, USA). Samples were also observed for high counts of anatoxin and cylindospermopsin producing species such as *Anabaena* (CIDA 2002). HPLC analysis was used to determine the chemical composition of the algal toxins.

Findings show that algal blooms were thicker and more frequent in Murchison Bay than Napoleon gulf. Highly toxic blue-green scum (*Microcystis* and *Anabaena* spp.) and water hyacinth congregated along the shore of Gaba water intake sites. Microcystin test kit results were lower than 0.5 ppb on all samples except for one station in the Napoleon gulf that showed a microcystin level of 0.5 ppb. In the inner Murchison Bay, some samples had microcystin toxin levels ranging from 0.5 ppb to 3 ppb. Microcystin levels observed were higher than the WHO guideline of 1.0 ppb in the inner Murchison Bay (CIDA 2002).

The study concludes that NWSC water treatment facilities at Gaba 2 are adequate for removing cyanobacteria from their intake water. However, the age or stage of the particular cyanobacterial bloom was not determined. It appears that the cells had not yet lysed and the toxins were still contained within the cells. There is still a possibility that an older deteriorating bloom may rupture and release toxins, before or during water treatment. This would expose the residents of Kampala to moderate levels of microcystins. Many people in the rural areas use Lake Victoria water directly from the shoreline for domestic purposes. Toxic cyanobacteria are present at dangerous levels and must be having negative health effects on the lakeshore communities and livestock of Lake Victoria (CIDA 2002).

Water Vectored Diseases

FIRRI Bilharzia Study

Bilharzia (also known as Schistosomiasis) is the disease caused by a blood borne fluke (Trematode) of the genus *Schistosoma*. The intermediate hosts of the genus *Schistosoma* are snails.

Adult schistosome worms live in a mammalian host, and these adult worms were first discovered in an Egyptian patient in 1851. The snail link was not discovered until after the turn into the 20th century. Schistosomiasis is the second most prevalent tropical disease in Africa after malaria and is of great public health and socio-economic importance in the developing world. There are five major species of the genus *Schistosoma* which infect man. One is found in Africa and in South America, two are confined to Africa, and the other two are found only in the Far East in China and the Philippines. *Schistosoma mansoni* is responsible for all the cases in Uganda (Odongkara 2000; Kadama *et al.* 2001). Intestinal schistosomiasis is a widespread public health problem in Uganda. Prevalence typically is highest near the lakeshore and along large rivers. No transmission occurs at altitudes >1400 m or where total annual rainfall is <900 mm, limits which can help estimate the population at risk of schistosomiasis (Kabatereine *et al.* 2004).

A study on the prevalence of Schistosomiasis around the riparian districts of Lake Victoria, Uganda, has been carried out by the FIRRI. The study addressed the intensity and spread of Schistosomiasis in the fisher folk communities at the Lake Victoria shores in relation to the obligate snail populations. The distribution pattern is probably determined by people's activity particularly fishing that brings them in frequent and prolonged contact with water. The districts most affected include all those that have shores along the Lake Victoria basin.

The study was carried out in six districts around Lake Victoria. These districts included Mukono, Jinja, Iganga, Bugiri, Busia and Kalangala. 271 adult respondents were randomly selected from 17 landing sites of Lake Victoria. Questionnaires were administered and samples of urine, stool and blood were analysed. The issues investigated included intestinal infestations, environmental public health, water and sanitation, and nutrition aspects. The symptoms covered included persistent abdominal complaints, stool stained with blood and bloody diarrhoea. While under the health and nutritional status, key issues were availability of latrines, clean water and food consumption.

The final reporting from the study indicated that out of the 271 respondents screened for *S. mansoni*, 140 were infected, giving a prevalence of 51.6%. However, percentage cases per district varied from 45.6% in Iganga to 60% in Jinja (Figure 8). Common periods in the year in which people mostly felt sick were the months of March to May that mostly coincides with the major rainy seasons. The study also indicated that about 65% of the respondents take water from the lake for domestic use. Collection of water from the lakeshore is mostly done by women (64%), making them more vulnerable to the disease. Results indicated that 57% of the fisher folk had acquired primary education, while 24% had not acquired any formal kind of education. Fisher folk vulnerability to Schistosomiasis was further enhanced by inaccessibility to both health facilities and personnel. The nearest health centres to most of the population were in a distance more than a kilometre while extension services by health workers were unsatisfactory. The findings suggested that water quality of the lake was deteriorating, which factor supports the growth of the intermediate host.

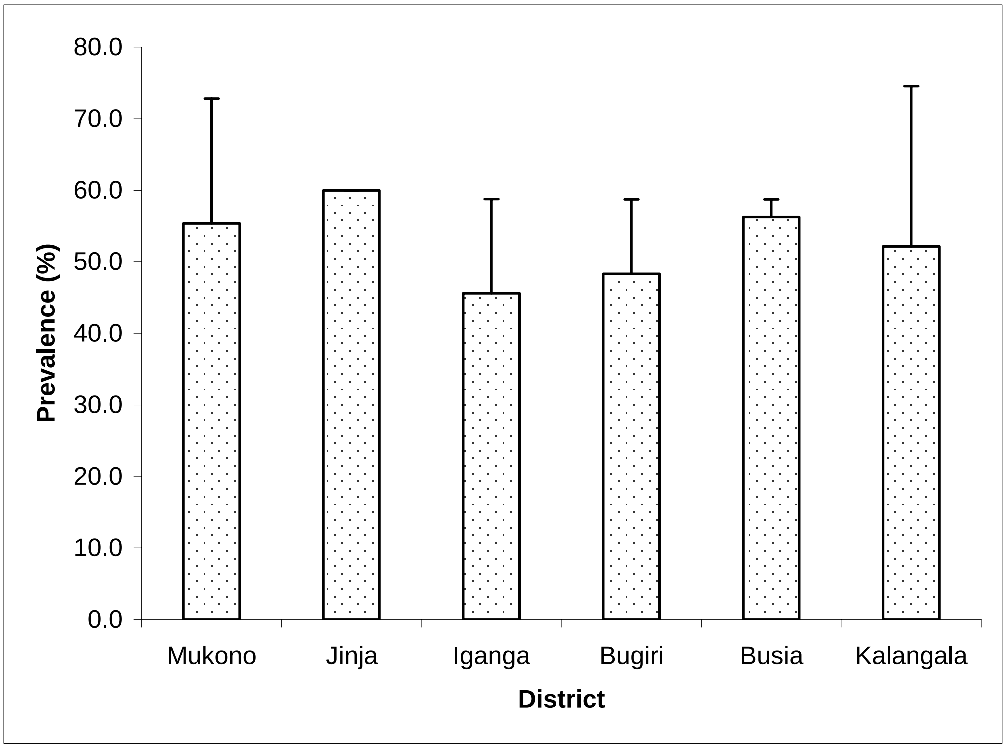

FIG. 8. Prevalence of Schistosomiasis in six lake districts around Lake Victoria, Uganda (Kadama 2001).

The MoH Bilharzia Study

The Vector Control Division in the MoH has the responsibility for implementing the National Schistosomiasis Control Programme. During the period 1998-2002 the division undertook a comprehensive survey on the prevalence of bilharzia in lakeshore communities (fish landing sites and schools), supported by the Centre for Disease Control (CDC) in USA. The Ugandan Government launched their campaign against Schistosomiasis in March 2003, and already about 500,000 people have received treatment (Schistosomiasis Control Initiative 2005).

The summary results are presented in Figure 9. It shows that the lowest prevalence of bilharzia is on the southwestern shoreline, close to the Tanzanian border, and increasing towards east and the Kenyan border. The highest prevalence by district is in Bugiri (54.8%), followed by Mukono (54.3%) and Kalangala (45.1%). It is noted that Bwondha Primary School at Bwondha landing site (Mayuge District) has a prevalence of 89.1% in this study, well above the district average. It also shows that the bilharzia prevalence in school children is lower than the landing sites communities in general indicating that the students may benefit from being in school and away from lake waters for prolonged periods of the day.

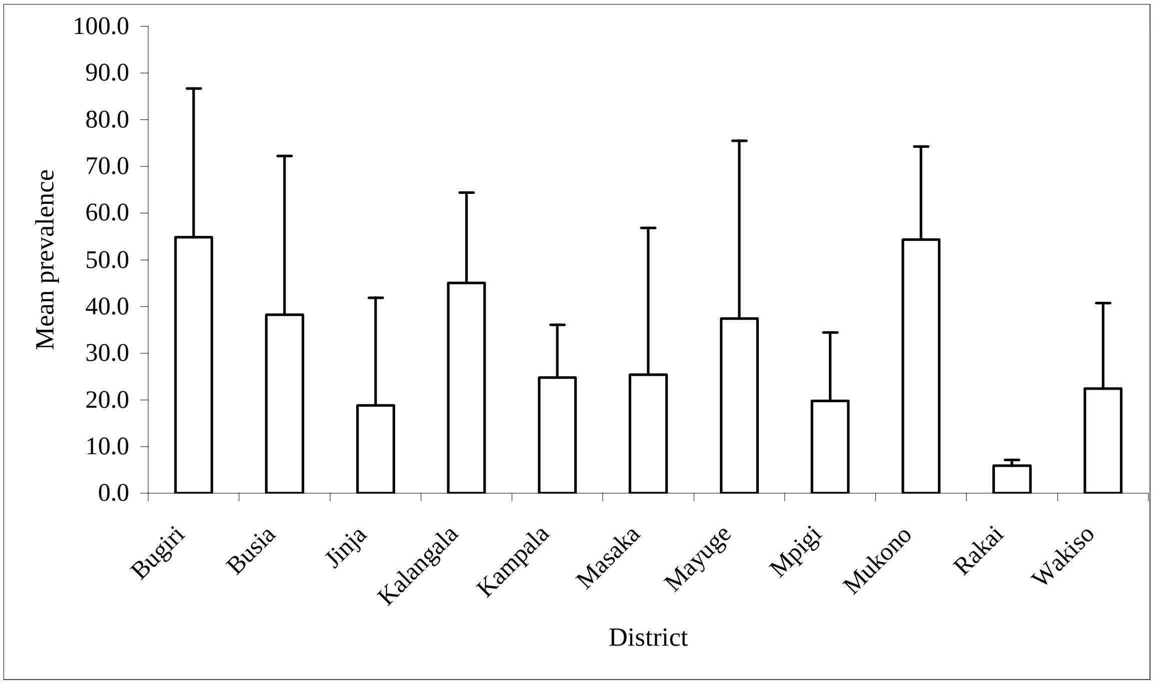

FIG. 9. Prevalence of Schistosomiasis in Lake Districts of Uganda (MoH 2005)

The MoH used the Kato-Katz method while FIRRI used the concentration method and the results were somewhat different, being slightly higher for FIRRI than of the MoH (Figure 10), except for Jinja and Busia where the differences were very high. This could be explained by the current mass Schistosomiasis treatment exercise by the MoH which has been ongoing since 2003 (Schistomiasis Control Initiative 2005) and yet the FIRRI study was conducted between 2000 and 2001. The 1998 to 2002 MoH study reported that the prevalence of bilharzia was generally <20% in the south-west of Uganda away from Lake Victoria, and >50% close to Lake Victoria (Kabatereine *et al.* 2004). The prevalence decreased as the distance from the Lake Victoria increased; this is expected as contact with water decreases.

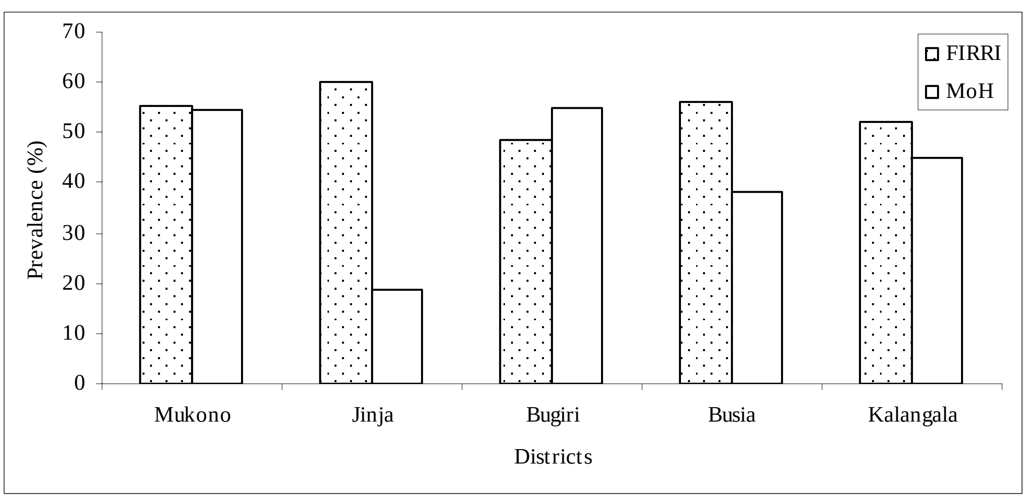

FIG. 10 Comparison between FIRRI and MoH prevalence on bilharzia in selected lakeshore districts.

Another study by the Ministry of Health in Mayuge district, where sanitation is very poor, and at shallow shoreline sites (<10 cm) showed that Biomphalaria was in great abundance. *S. mansoni* infections were found in children as young as 9 months old (Schistosomiasis Control Initiative 2005). Another study by Takuhebwa (2001), to establish the magnitude of bilharzia and its related environmental risk factors in communities close to Lake Victoria and Busiro County in Mpigi district, showed that about 55% of the population were infected with bilharzia, and in average in all the four villages studied, hookworm infections accounted for 37%. There was a significant difference in bilharzia prevalence between those who used latrines regularly and those who did not have, as parasitic eggs of *S. mansoni* are released into the environment from infected individuals, rupturing on contact with fresh water to release the free-swimming miracidium. About 84% of the population fetched water for domestic use from the lake. Observations indicated that about 85% had no latrines.

Waterborne diseases in riparian districts

Figure 11 shows the trend in cases of cholera, dysentery and typhoid fever in the riparian districts of Lake Victoria for the first 13 weeks of 2003, 2004 and 2005 (MOH 2005). Cholera cases were highest in Kampala for the three years, while many districts did not report any cases of the disease. Cases of dysentery were high in most of the districts and highest in Wakiso followed by Kalangala. Typhoid fever seemed to follow a similar trend as dysentery with districts having the highest prevalence of dysentery also having high prevalence of typhoid fever.

Malaria

Ninety three percent of the total population in Uganda is at risk from malaria. Although all four species of malaria parasites exist in Uganda, *Plasmodium falciparum* is responsible for over 95% of cases. Major vectors are *Anopheles gambiae s.l.* (and within the complex mainly *A. gambiae s.s.*) and *Anopheles funestus*. The number of malaria cases reported by the MOH (2005) has steadily risen over the past 14 years (MOH 2005). It is estimated that up to 100,000 deaths occur due to malaria every year in Uganda, most of them in children below five years. The vector mosquitoes require access to standing water to complete their life cycles as eggs are deposited and larvae grow to adults in water. Where malaria is found depends mainly on climatic factors such as temperature, humidity, and rainfalls. Malaria is transmitted in tropical and subtropical areas, where *Anopheles* mosquitoes can survive and multiply and malaria parasites can complete their growth cycle in the mosquitoes. Temperature is particularly critical, for example, at temperatures below 20°C, *Plasmodium falciparum* (which causes severe malaria) cannot complete its growth cycle in the *Anopheles* mosquito, and thus cannot be transmitted. Malaria cases have been observed to increase following a weather change, which favours the vectors.

Malaria contributes to by far the major share of the disease burden in the country, with 39% of outpatient visits and 35% of inpatient admissions. There has been an increasing trend in clinically diagnosed malaria cases reported in the Health Management Information System (HMIS) for governmental and nongovernmental organizations [NGO] health facilities from 5 million in 1997 to 16.5 million cases in 2003 (MoH 2005). Currently, malaria-prevention efforts in Uganda include control of breeding grounds of the mosquito vectors, the use of insecticide-treated mosquito nets, and anti-malarial drugs (especially for expectant mothers). The Ministry of Health is also proposing to use DDT as an indoor residual spray to kill the vector mosquitoes. DDT was initially introduced for control of vector-borne diseases, including malaria; however, it was banned in the United States in 1972 because of potential harmful effects on humans, wildlife and the environment. Since it is a potential human carcinogen, the United Nations Environmental Program (UNEP) has restricted its use in developing countries until alternative methods of vector control are sought (Jaga and Dharmani 2003). The use of DDT for controlling malaria should be carefully researched before its application as mosquitoes may become resistant to it and its non-specificity as a pesticide amongst other potentially environmentally harmful attributes. Also, Uganda may lose its present EU and American agricultural-product and fish markets, because the insecticide accumulates in the food chain, posing health risk to humans.

Among children, malaria causes childhood anaemia, stunting and mental retardation. Among pregnant women, malaria causes maternal anaemia, premature births, low weight babies, still births, abortions and miscarriages. Malaria does not only cause ill health and deaths but also has a great impact on the economic developments of the individual, the family, the community and the nation at large. This is mainly through treatment seeking, treatment costs, and on prevention.

Malaria interferes with economic activities thus causing poverty in families, and also causes absenteeism from school. Malaria is therefore a leading cause not only of ill health and death in Uganda, but also of poverty in the country. Figure 12 presents the prevalence of clinically diagnosed cases of malaria in some districts of Uganda (MoH 2005). Nation wide, Lake Victoria riparian districts show very high prevalence of malaria. Generally, as you move from western to eastern Uganda, there is an increase in the prevalence of malaria. This is in agreement with earlier findings that quality of life decreased as you move from western to eastern Uganda (LVEMP 2003).

AIDS

Ever since the first HIV/AIDS case was diagnosed in Uganda in 1982, over 2.2 million people have been infected and about 838,000 have died, leaving behind close to 1.7 million AIDS orphans. HIV/AIDS has unleashed severe impacts on children and the country as a whole, notably, the straining of the health system, socio-economic disruptions, reductions in productive capacity, increase in AIDS orphans, with related problems such as street children and child abuse, and it has also exacerbated poverty at household and community levels. However, Uganda still faces the challenges of inadequate information and facts pertaining to the prevalence of HIV/AIDS infection as well as determining the effectiveness of alternative strategies in interrupting or completely stopping the further spread of HIV/AIDS.

Uganda holds about 0.4% of the World’s population, but accounts for 2.4% of the HIV/AIDS cases. The number of cumulative AIDS cases has continued to rise as a result of a large pool of HIV infected people who fall sick (UNICEF- IRC 2002). The first two cases of AIDS identified in 1982 were from Rakai District on the shores of Lake Victoria. AIDS cases were limited to high-risk groups such as commercial sex workers, and youth with multiple partners. Kampala, Masaka, Jinja and Rakai were observed to have more than 500 AIDS cases per 100,000 residents (UNICEF-IRC 2002). The large number of cases in Kampala and Jinja is attributed to the high concentration of urban residents whereas in Masaka and Rakai it is mainly due to the fact that HIV/AIDS was first identified in these districts. In the districts of Rakai and Masaka where the epidemic was first reported, HIV prevalence ranges between 10-13 percent.

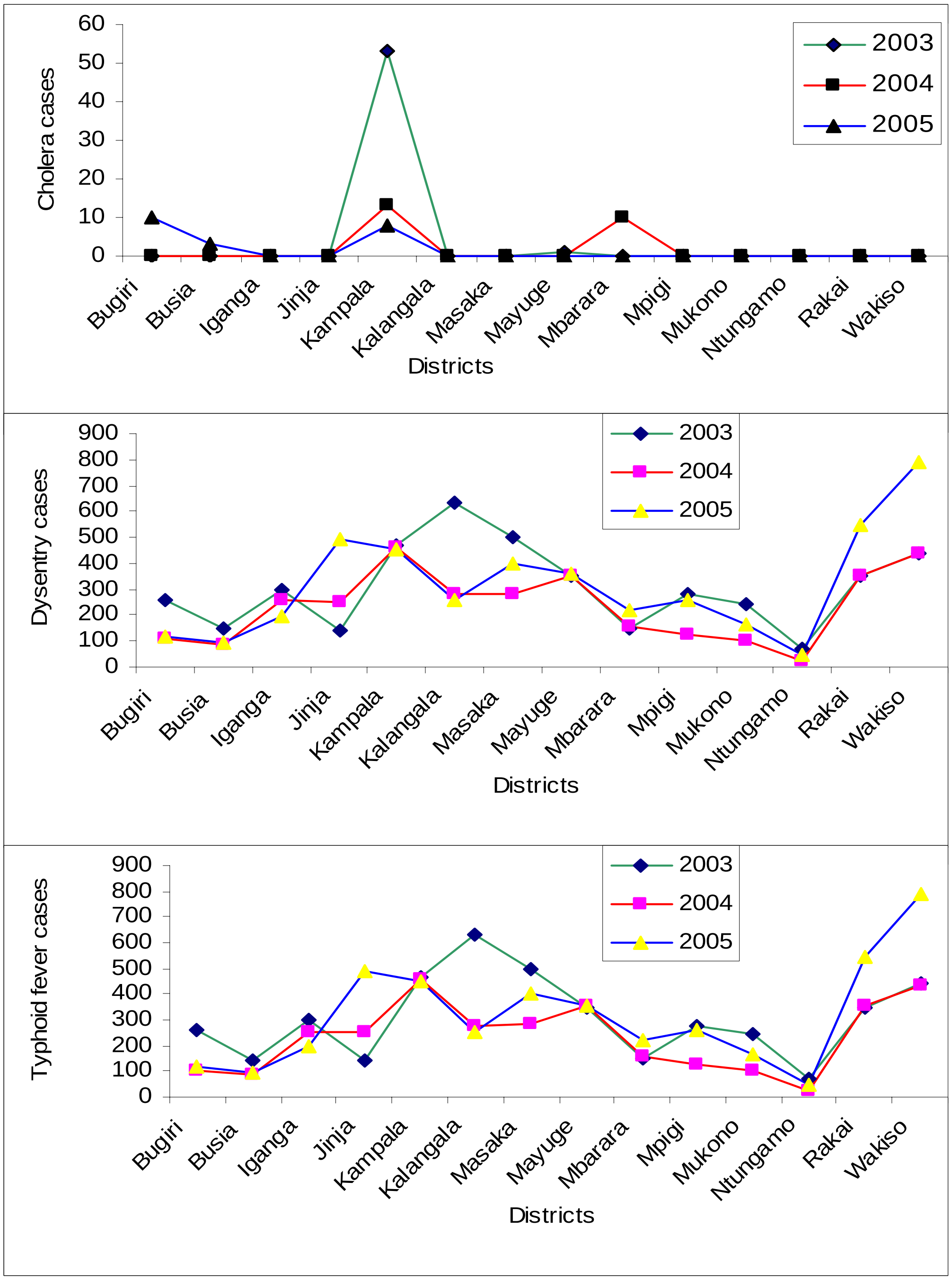

FIG. 11. Trends in waterborne diseases in selected districts in the catchment. Source: MoH 2005.

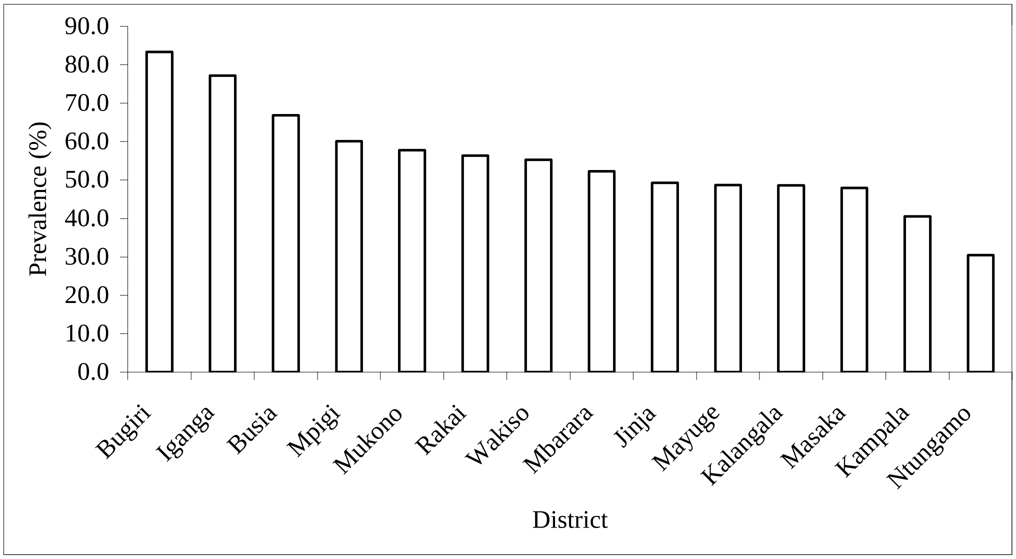

FIG. 12. Prevalence of malaria for the year 2004 in some districts, Uganda.

Alcohol selling is one of the income-generating activities in Uganda being adopted by women, but it is also associated with risky sexual behavior. Alcohol consumers often interact with barmaids, and under the influence of alcohol buy sex. In addition, married women and men often use drinking places and hotels as meeting points with extramarital partners with whom they have sex. Alcohol consumption at social occasions such as weddings, last funeral rights, circumcision rituals, graduation parties and discos are still associated with high levels of sexual activity and rape, which is suspected to increase HIV infections. This alcohol consumption centered lifestyle is the observed lifestyle around most of the landing sites around Lake Victoria. The situation in landing sites is aggravated by the high mobility of the populations and high rates of immigration.

It was found out that because of their large proportion of migrating persons, the fishing villages presented populations with high risks for HIV infection (LVEMP 2002; UNICEF-IRC 2002). A survey in Rakai showed that 25% of the households were cultivating less and less lands. Of these 35% attributed it to HIV/AIDS related sickness or death. This has threatened food security of affected families, worsened the nutritional status at household level, and led to a decline in cash-crop production.

Figure 13 compares disease burden in selected districts in Lake Victoria basin. Among the three diseases compared, malaria is the most prevalent followed by AIDS. The worst hit district is Mukono for malaria and Kampala for AIDS.

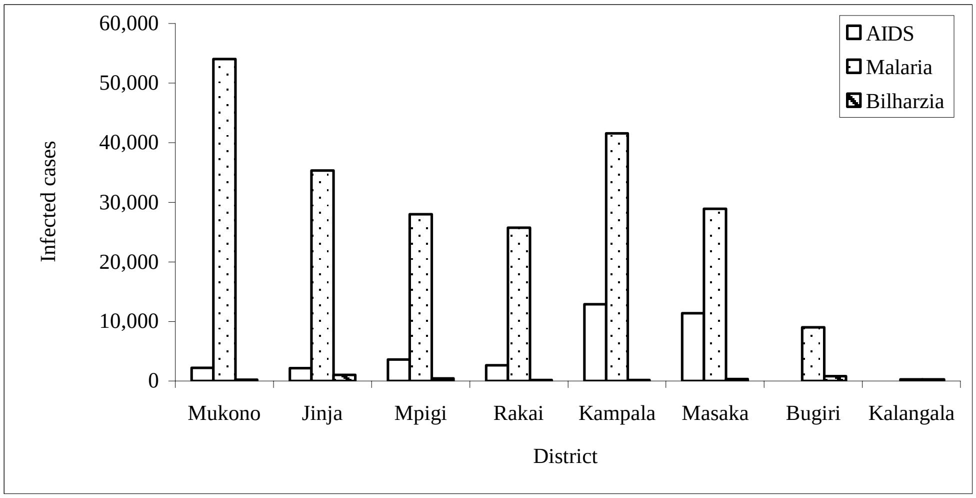

FIG. 13. Disease comparisons in populations of selected riparian districts.

AIDS and sexually transmitted diseases (STDs) were reportedly common at the landing sites due to the high rate of prostitution, lack of safe sex, and existence of migrant HIV-infected persons (LVEMP 2002). The common STDs were sores in the genital parts, gonorrhea and syphilis.

Other projects

Kawempe Primary Health Care Project is an urban area project implemented by Save the Children (UK) in partnership with Kampala City Council (KCC) Kawempe Division and funded by the Department for International Development (DFID). The project goal was to improve the health status of children and the community where they live and the project purpose was to reduce the prevalence of most common diseases affecting children and communities where they live.

Access to health education by the community was increased during the project, through various means, accompanied by improved access to better sanitation facilities (amongst others by constructing latrines, bath places, garbage bins and drainage systems) and improved water access. Significant improvements in terms of sanitation were evident in the project area. The project had also increased the number of safe water facilities, resulting in reduced cost of water in the area. The project facilitated an increase in available vital information on health. The project made several accomplishments towards the reduction of common illnesses among children and general population, and reduction in indiscriminate faecal disposal and a reduction in the prevalence of diarrhea in the community.

Uganda Bureau of Statistics (UBOS) undertakes socio-economic household surveys in the country (Appendix 1). These comprehensive surveys do not reveal any information directly related to water and health, but give a good indication of the relative socio-economic situation in the various districts. This gives planning good guidance as to where specific measures to improve peoples' quality of life, including reducing prevalence of various diseases.

Table 1 presents distribution of hospitals and the catchment population they serve. It is observed that the number of hospitals in relation to the population they serve is very inadequate and there is no proportionality in the distribution of hospitals. Control, prevention and treatment of disease can be best achieved if there is adequate health facilities in any settlement. As seen in Table 1, health facilities for the riparian communities are inadequate especially so for the riparian districts of Busia and Kalangala that have no government-aided hospital at all. This aggravates the situation since riparian communities do not have access to health educators to sensitize them on safe health practices and prevention of water-related and other diseases.

TABLE 1. The distribution of hospitals by districts and the availability of the same to the population

District	Population	Hospital
Bugiri	426,522	1
Busia	228,181	0
Iganga	716,311	1
Jinja	413,937	3
Kalangala	36,661	0
Kampala	1,208,544	13
Kamuli	712,079	1
Masaka	767,759	3
Mayuge	326,567	1
Mbarara	1,089,051	2
Mpigi	414,757	2
Mukono	807,923	4
Ntungamo	386,816	1
Rakai	471,806	2
Wakiso	957,280	4

Source: UBOS (2005)

Conclusions

Malaria continues to be the most prevalent water related / waterborne disease for Uganda followed by dysentery in the riparian districts. Lowest prevalence of malaria and bilharzia is on the south western shoreline close to Tanzanian boarder, and increasing towards the east and Kenyan boarder. Malaria is highest in Bugiri, followed by Iganga and Busia while the lowest is in Ntungamo. Highest bilharzia prevalence is in Bugiri, followed by Mukono and Kalangala.

Of all the waterborne diseases, dysentery is the most common, followed by typhoid fever and cholera respectively. The most affected districts included Wakiso, Kampala and Kalangala.

Highly toxic blue-green scum consisting of *Microcystis* and *Anabaena* spp. congregate along the shore of Gaba water intake sites. In the inner Murchison Bay, microcystin levels observed were higher than the WHO guideline, posing a threat to human and other animal health. Water treatment for serviced communities can lower the risk but for un-serviced communities or those taking water directly from the lake, algal toxins pose a greatly increased risk as over-eutrophic conditions cause eutrophication that cause algal blooms dominated by toxic cyanobacteria.

AIDS and STDs were reportedly common at landing sites due to high rates of prostitution, lack of safe sex, and existence of migrant HIV infected persons. Kampala, Masaka, Jinja and Rakai were observed to have the highest numbers of AIDS cases. High mobility and high rates of immigration to landing sites, together with increased cash flow because of the fishery makes landing sites focal centers for HIV/AIDS and STD transmission.

The 2002 Uganda census report, shows that 17 percent of Uganda's population had no access to toilets or latrines; and only 55 and 62 percent of the rural and urban populations respectively had access to safe water (UBOS 2005). Some riparian districts have low water and sanitation coverage, for example, the district water coverage for Rakai is 42.6%.

Recommendations

LVEMP 2, in Uganda (and all the three countries), should draw on the information and capacity created in LVEMP 1 and be much more focused towards tangible actions to benefit the population living around the lake (and in the basin). No doubt, the reduction of water-borne and water-related diseases will largely contribute to improved standard of living for the riparian communities. This could be achieved by introducing a **Human Health Component** under LVEMP 2. This component should have increased sensitisation / health education, combined with improvement of sanitary structures, as the main focus. Improved quality of domestic water supply in a limited number of selected locations could be included in such programme. Minor low-cost locally initiated infrastructure development, should be the starting and focal point.

- The activities should primarily be concentrated in the worst-off / poorest areas, with reference to statistics for the various districts and landing sites, and other ongoing programmes in these areas.
- It must be focused towards changing peoples' hygiene habits and behaviour patterns (including getting rid of possible socio-cultural taboos), supported by low-cost infrastructure development (latrines, and small water supplies.) to enable practicing the behavioural changes.
- It must have along-term approach (10-15 years), as changing peoples' minds is not done overnight.

The use of cheap, sustainable home-based methods of purifying / treating water from homes in particular should be researched upon, for example, the potential use of plants such as moringa (*Moringa oleifera* Lam.) to treat water in homes should be experimented. If found to be viable, this could have other potential benefits besides treating water, such as provision of fuel wood, medicine and acting as wind breaks.

The attendance of compulsory Universal Primary Education (UPE) for all school-age children must be ensured to improve literacy level, which will in turn improve better hygienic and sanitary practices. Functional Adult Literacy programs by LVEMP 2 in collaboration with the Ministry of Gender, Labour and Social Development should be carried out to raise the literacy level of adults in the districts.

The exposure to algal toxins has increased because of eutrophication and is an increasingly important but understudied risk factor for the health of lakeshore populations. Further study is needed to define the risk and solution to the eutrophication that is the cause of the cyanobacteria dominance will require regional action although locally eutrophied waters such as Murchison Bay can improve through local action.

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Appendix 1
Distance to Nearest Social Services and Water Source of Households by District

District	Health Facility		Water Source	
	Up to 5 kms	**Over 5 Kms**	**Up to 1 Km**	**Over 1 Km**
Kalangala	6,177	6,573	11,025	905
Kampala	288,759	17,419	222,329	4,442
Masaka	139,504	37,378	127,989	40,074
Mpigi	64,819	23,835	65,266	20,903
Mukono	130,843	57,124	152,498	26,275
Rakai	84,164	22,521	68,492	34,638
Wakiso	186,128	32,014	174,597	18,541
Bugiri	60,375	22,374	54,349	25,085
Busia	39,355	8,531	39,207	6,871
Iganga	119,709	20,516	110,301	25,065
Jinja	81,052	2,973	61,676	8,349
Mayuge	43,632	20,373	45,248	15,496
Mbarara	147,446	77,374	135,476	75,258
Ntungamo	59,774	16,654	59,999	12,994

Source: Uganda Population and Housing Census 2002.