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Assessment of Possible Sources of Endocrine Disruptors and Microbial Pathogens and their Impacts in the Lake Victoria Basin in the East African Region

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Abstract

This study was conducted from August 2008 to May 2009 in Mwanza (Tanzania), Jinja (Uganda) and Kisumu, Homabay and Suba (Kenya) to establish the sources of pollutants in particular endocrine disruptors and microbial pathogens in water and fish. A sociological study was undertaken using qualitative and quantitative methods. Microbial contamination of water and fish in the lake was assessed in 14 water and 60 fish samples in Mwanza. In Jinja, assessment of microbial contamination was carried out in 100 water and 26 fish samples. A total of 80 Nile tilapia were collected from Kisumu, Homabay and Suba and examined for gross pathological lesions using standard necropsy techniques. Findings from the sociological studies indicated that, the knowledge and awareness on endocrine disruptors in the region is low. Pollutants that find access into the lake and have potential for disrupting the endocrine systems exist in all cities and originate from point and non-point sources. Human, industrial, agricultural, hospital and domestic wastes are the main sources of pollutants likely to contain endocrine disruptors. These pollutants are handled poorly and most of them are disposed off into the lake without treatment. In Mwanza, contamination of water with faecal material at various landing sites was observed in 85.7%, 78.6% and 35.7% of the samples determined using Total Viable Counts, Total Coliform Counts and Total Faecal Coliform Count. All water samples were negative for S*almonella* spp, *Vibrio* spp, *Cryptosporidia* spp and *Giardia* spp. In Jinja, microbial contamination was observed in all sampling sites as determined by aerobic plate count (APC), Total Coliform Count (TCC) and *Escherichia coli* count. There was no significant difference in microbial load between sampling sites ($P > 0.05$). The gross pathological lesions were generalized hyperemia, liver changes (paleness, grey spots and hemorrhages), cystic urinary bladder, atrophied testis and kidneys, eye opacity, degenerated ovaries, grey patches on the stomach, clear cysts in the testis, deformed dorsal fin and ulcers on the lateral side of the body. Further studies are underway to confirm the likely causes of the observed lesions and the impact of the observed pollutants and microbial pathogens.
Key words: Pollution; Endocrine disrupters; Faecal materials; Pathological lesions

Introduction

Lake Victoria is the second largest freshwater lake in the world, which is central to economic development in the East African region (Anon, 1998). The lake region and its catchment are

vital to the livelihood of over 160 million people living in various counties within the Nile Basin (Odada *et al*., 2004). Economic development of this region is primarily based on agriculture, agriculture-based industries, fisheries, mining and tourism. Despite its potential contribution to the economic development, Lake Victoria is under considerable pressure from a variety of interlinked human activities. It has undergone enormous environmental degradation within the last 40 years. Overfishing, siltation from the erosion of deforested watersheds, introduction of exotic species of fish and plants, industrial pollution, eutrophication and climate change contribute to rapid evolving changes in the lake that seriously threatens the functions of ecosystems and overall biodiversity (Odada *et al*., 2004; TED 2007). These and other related environmental and social factors have seriously impacted Lake Victoria's fish population as well as the livelihood of inhabitants in the lake region.

The rapid growth of human population in the lake region has increased pollution levels which is known to interfere with optimal productivity of fish (Odada *et al*., 2004). On the other hand, environmental pollution particularly microbiological, eutrophication, heavy metals, pesticides, as well as industrial and domestic effluents have been identified as important causes of loss of biodiversity and reduced productivity in fish in the lake (Leaños-Castañeda *et al*., 2002; Odada *et al*., 2004; Henry and Kishimba, 2006; Ikingura *et al*., 2006). Urban areas around the lake are also sources of untreated sewage as well as industrial and domestic effluents that contain mixed chemicals and microbial pathogens (Odada *et al*., 2004). These pathogens and chemicals have the potential to cause diseases and mortalities in fish as well as contamination of fish products leading to their reduced quality and commercial value. Although several studies have been carried out to assess the extent of water pollution and contamination of fish in the lake, limited studies have investigated the presence of pollutants likely to contain endocrine disruptors and their impact on productivity of fish. The aim of this study therefore was to establish the sources of pollutants and determine if they contain endocrine disruptors as well as their effects on sustainable productivity of fish in the Lake Victoria. In addition, the extent of contamination of water and fish with bacterial pathogens in an attempt to improve their management, safety and market value was assessed.

Materials and Methods

Study areas

The study was carried out in Mwanza (Tanzania), Jinja (Uganda) and Homabay and Suba (Kenya) from August 2008 to June 2009. Whereas the sociological studies were carried out in all the adjacent urban centres, microbial contamination of water and fish was assessed in Mwanza and Jinja, while pathological changes were investigated in fish from Homabay and Suba only.

Study design

Cross sectional sociological studies were carried out in all cities using both qualitative and quantitative data collection methods. Qualitative data collection involved reconnaissance surveys, participant observations, case stories, in-depth interviews with key informants as well as focused group discussions. Quantitative data were collected using questionnaire surveys. These methods were used to gather information on sources of pollutants in particular those likely to contain endocrine disruptors and causes of decline in fish productivity and quality of fish and fish products. Assessment of microbial contamination of water and fish

was carried out in Mwanza (Tanzania) and Jinja (Uganda) using standard protocols (Quinn *et al*., 1998). Pathological examination was carried out in fish samples that were collected in Kisumu, Suba and Homabay, Kenya using protocols described by Roberts, (2001).

Data collection

Survey of key informants

In Tanzania informal and formal data collection methods were used to collect information from key informants. The city council was the first entry point for researchers to gather general information on major activities and possible pollutants and their sources, major environmental problems and control measures currently being taken. Within the city council, key representatives working in agriculture, fisheries, urban planning, environment and tourism, health and Water and Sewerage Authority departments were visited. Lake Victoria Environmental Management Project (LVEMP), Nile Perch Industry, Pharmacy and Veterinary drug stores, Zonal Veterinary Investigation Center in Mwanza, National Fish Quality Control Laboratory in Nyegezi Mwanza were visited. A reconnaissance survey in proposed sites for data collection was carried out through informal interviews with key people in order to get a general sense of major pollutants and their sources. Focus group discussions (FGDs) were conducted in particular with fishermen to get specific information on fishing and their perceptions on the amount of fish in the lake. Using a pre-tested questionnaire for individual interviews, 108 interviews were conducted in two wards.

In Uganda, data were collected using an environmental screening tool, matrix ranking, case stories, key informant interviews and observation. Focus Group discussions were held with fishermen, fisherwomen, community members and boy and girl children aged 12-18 years. One of the discussions included a mixture of fishermen and fisherwomen while the rest had fishermen only. Community members and children were also disaggregated by gender. Fisherwomen, who are rare, were represented by 4 fisherwomen during discussions. Children were selected for participation in discussions because of the household role they play of cutting fish for cooking and therefore likely to have some knowledge about abnormalities in fish. They are also involved in waste disposal in households.

In Kenya, the study was carried in Homa bay and Suba districts. The FGDs involving 15 men and 15 women, each were carried out by the researchers at Suba and Homabay. During group discussions, a range of questions were asked to capture information related to description of sources and nature of wastes disposed, disposal methods, impact and severity of pollutants, extent of impact, duration and frequency of impact, health, social and cultural impact and strategies to minimize their negative impact. Matrix ranking was mainly used to identify and rank the common wastes existing in communities and particularly those that are produced in bigger quantities than others as well as those that end up in the lake more than others. Key informant interviews were held with members of the agriculture, fishing, fish marketers, employee of fish processing industries, beach management unit committees and some district personnel in the fishing and health departments. They provided information under the same variables as those in group discussions as mentioned above. Observations were made particularly in the way wastes were disposed into the lake. The lake waters were observed for any changes and the fish for any abnormalities. These observations were meant to verify what was reported by participants and respondents and to provide any relevant added data

that was not captured through other methods of data collection. Questionnaire survey was carried out using interviews that were administered by the researchers themselves. Using a pre-tested questionnaire for individual interviews, 104 individual interviews were conducted in two wards.

Analysis of water quality and microbial pathogens in fish

In Tanzania, screening of water samples for quality and contamination with microbial pathogens was carried out in samples that were collected on fish landing sites in Mwanza. Samples were screened for Total coliforms, Total Faecal Coliforms, Total Viable Counts, Salmonella, Giardia and Cryptosporidia using standard protocols (Quinn *et al*., 1998). A total of 28 water samples and 60 fish from 14 different sampling sites were collected for assessment of microbial contamination. About 1,000 ml of water was collected in duplicate from each of the sampling points using sterile bottles and divided into 5 portions for analysis of Total Fecal Coliforms (TFC), Total Coliforms (TC), Total Viable Count (TVC), *Salmonella, Vibrio, Cryptosporidium* and *Giardia.* Enumeration of total viable bacteria, total coliforms and faecal coliforms in water samples was carried out using methods described by Quinn *et al*. (1998). Total viable count technique was used to estimate the number of viable bacterial found in water sample. A ten-fold serial dilution of the sample was made using peptone water (0.85% in normal saline). One ml of diluted water was place in a sterile petri dish in triplicate. Twenty ml of molten Nutrient Agar cooled at 42^{o}C was added, and then mixed by rotating the plate to allow uniform distribution of bacterial throughout the agar. After solidification of the media, inoculated petri dishes were incubated at 37^{o}C for 48 – 72 hours. Counting was made to colonies and the mean number computed. The average number of colonies was multiplied by the dilution factor, logarithmicaly transformed and reported as colony forming units of viable bacteria per ml. Total coliform count technique was used to estimate the number of coliform bacteria found in water sample. Similar method as for total viable count was used with exception that diluted water samples were incubated on violet red bile agar (VRBA) special media. Total faecal coliform count technique was used estimate the number of faecal coliform bacteria found in water sample. The same method as for total coliform count was used except that the incubation temperature was 44^{o}C.

For isolation and identification of *Salmonella* and *Vibrio,* the procedure described by Quinn *et al.* (1998) was used. Suspected and identified isolates were stored in nutrient broth mixed with 50% v/v glycerol at –20^{o}C for future studies. *Cryptosporidium parvum* oocysts in water were demonstrated by the acid fast (Ziehl-Neelsen) staining method (Quinn *et al*., 1998). The prepared smears were examined under the microscope using 10x and 40x objectives. Detailed morphology of the oocysts was confirmed using the oil immersion at 100x objective. The water sample was centrifuged at 3000 x g for 5 min and the sediments were recovered and used for preparation of smear. The smear was emulsified in saline and Lugol's iodine mixture and a cover slip was placed on top of the mixture and the entire coverslip area was examined systematically under the microscope using the 10x objective for demonstration of *G. lamblia* cysts. The 40x objective was used to confirm suspected parasites.

Screening of fish for microbial contamination and pathogens was done in 60 fish samples that were collected from 14 different sampling sites. From each sampled fish, culture was made for surface, gill, liver and kidney samples. All these samples were screened for aerobic

bacteria using procedures described by Stoskopf, (1993) and Roberts, (2001).

In Jinja Uganda, water and fish samples were collected. Assessment of water quality was carried out on water samples that were collected from shoreline of rivers/streams/drainages that pour into the lake as well as other areas thought to be potential sources of pollution into the water. From each of the sites samples were collected three times on monthly interval between August and November 2009 for comparison of the changes in the microbial load. The samples were examined for total aerobic counts, total coliforms, *E. coli* and pathogens (*Salmonella* spp and *Vibrio* spp.) that cause contamination of water and fish. A total of 100 water samples from 16 different sites were collected and 26 fish as well for assessment. Surface water samples were collected by hand using autoclaved 250 ml bottles and screw caps, from approximately 0 – 5 cm below the water surface. Collected samples were put on ice in a cool box and transported to the Faculty of Veterinary Medicine for analysis where they were processed on the same day of collection to avoid multiplication of microorganisms. Each of the samples was analyzed in duplicate and the counts averaged.

The samples were processed by serial dilution of the water samples using sterile peptone water in a ratio of 1:10. The samples were then thoroughly mixed to make a homogeneous mixture and inoculated within 15 minutes of blending to avoid further multiplication of the organisms. The surface spread method was used for total coliforms and *E.coli*, total aerobic plate counts and the streak method was used for the detection of *salmonella* spp and *Vibrio* spp. The total aerobic plate count was carried out using plate count agar (PCA) according to standard procedures (Microbiological Manual, 2000). The dilutions were selected to get a colony count of between 25 to 250 per petri dish and the counts made accordingly per ml of the original sample. The contents in the serially diluted tubes were thoroughly mixed by shaking or by use of a vortex mixer to enable separation of the individual microorganisms, which are assumed to produce a colony each. The surface spread technique was employed and 0.1ml of the dilutions was transferred onto duplicate plates for each dilution step and surface spreading was done using sterile glass surface spreaders. The plates were incubated at 37^{o}C for 24 - 48 hours. The number of colonies was multiplied by the reciprocal of the dilution and logarithmicaly transformed into log 10 cfu/ml for further analysis and reporting.

Enumeration of total coliforms and *E. coli* were done on Chromocult – coliform agar using similar procedures as described above with 0.1ml of the dilutions onto duplicate plates for each dilution and surface spreading and incubation at 37^{o}C for 24 hours. Pink colonies were classified as total coliforms, whereas dark blue colonies were classified as presumptive *E. coli* colonies. The counts were similarly made and recorded. A few colonies were confirmed as *E. coli* biochemically using the IMVIC reactions where colonies positive for *E. coli* are supposed to be indole (+) methyl red (+) voges proskaver (-) and citrate (-)

Detection of salmonella was performed by centrifuging 100 ml of the water sample so that the salmonella could be captured in the sediment. Fifty ml of the supernatant were poured off and the remaining portion pre-enriched for 24 hours at 37^{o}C using peptone water to allow multiplication of *Salmonella*. The pre-enrichment was followed by selective enrichment with Tetrathionate broth at a ratio of 1:9 for 24 hrs at 37^{o}C and incubated at 43^{o}C for 24 hours. The enriched cultures were streaked onto selective media (Xylose Lysine desoxycholate (XLD)) agar and incubated at 37^{o}C for 24-48 hrs and examined for typical *salmonella* colonies.

Salmonella colonies were expected to appear as large sized and completely black colonies. The suspected colonies of salmonella were sub-cultured to get pure cultures which were further confirmed using Urease, Tripple Sugar Iron (TSI) and citrate tests after stabbing the butt and streaking slant and incubating at 37°C for 24 hrs. *Samonella* in TSI culture typically produced alkaline (red) slant and acid (yellow) but with production of H_2SO_2 (Blackening). The citrate test was done by inoculating the *Salmonella* colony from the pure culture into citrate agar by making a straight stab and incubated at 37°C for 24 hrs. The medium changed from green to blue colour for a positive test. The results were recorded as either present or absent.

The detection of *Vibrio spp* particularly *V. cholerae* was done by centrifuging 100 ml of the water sample and enrichment of the 50 ml of the sediment using alkaline peptone water for 8 hours at 37°C. The cultures from each of the enrichment media were plated on Thiosulphate – citrate-bile salts-sucrose (TCBS) agar. The typical suspect colonies of *Vibrio* were picked and inoculated in TSI agar and Lysine Iron agar (LI) at 37°C for 24 hours. Cultures that showed acid slants (yellow) in TSI agar and alkaline slants (purple) and alkali or neutral butts in LI agar were further examined by inoculation on 1% Tryptone broth with and without 3% sodium chloride and incubated at 37°C for 24 hours. The microorganisms growing in the 3% sodium chloride medium were considered to be *V. cholera.* The results were recorded as either present or absent.

The microbiological quality of fish was assessed for the same organisms as described above. Samples were appropriately processed and different parts of the fish, namely surface washings, gills and intestines were analysed for microbial load and contamination with potential human pathogens in particular *Salmonella spp* and *Vibrio spp*.

Fish Pathology
Pathological examination was carried out in fish samples that were collected in Kisumu, Suba and Homabay in Kenya. A total of 80 fish were examined from Dunga Beach in Kisumu (21), Suba (15) and Homa bay (44). All fish were examined thoroughly for gross changes at the site of sampling and tissues collected for histology and endoparasites; and blood prepared and fixed for haemoparasites using standard protocols (Roberts, 2001).

Data analysis

Data were entered into Microsoft Excel and later imported into GraphPad Prism^R version 3.02 for Windows for statistical analyses in order to determine differences in bacterial load between the different sampling sites. Bacterial counts were transformed into $\log_{10}$ cfu/ml for water samples or cfu/g for fish. Differences in the means of triplicate counts for each of the three samples were analyzed using one-way analysis of variance (ANOVA). Categorical data were reported in proportions and compared using Chi-Squared test. Significant differences were tested at $p \leq 0.05$ in all the statistical analyses.

Results and discussion

Survey of key informants

Interviews revealed that the major sources of pollutants entering Lake Victoria through Mwanza were from industrial and agricultural activities that discharged effluents directly into the lake, or rivers and tributaries that drained into the lake. Unplanned residential settlements with poor sanitation were major sources of faecal discharges and other domestic wastes into the lake. Garages that do not have interceptors directly discharged contaminated materials that were washed by rainfall/surface runoff into the rivers or lake. Solid and liquid hospital wastes were disposed directly and indirectly into the lake and rivers. Chlorinated compounds from industries, garages, refrigerators as well as the other chemicals from hair saloons such as mercury containing make-ups and cosmetics also polluted the lake.

Low production of fish particularly Nile tilapia and reduced diversity of fish species in Lake Victoria has been attributed to pollution and over fishing due to increased number of fishermen and fishing gears. Use of illegal fishing nets, pesticides in particular Endosulfan and other chemicals also reduced fish abundance and diversity. Respondents had little knowledge of use of contraceptives as sources of pollutants and microbial pathogens.

In Uganda, major constituents of wastes observed at the landing sites and around residential areas were polythene bags, and agricultural, animal, industrial and medical wastes. Among the most likely sources of endocrine disruptors were human waste (fecal), agricultural and animal waste and soiled sanitary pads and contraceptive pills. The observation of contraceptive pills among the wastes was noted as a matter serious concern with potential to cause endocrine disruption in fish once they are improperly disposed.

The changes observed on the lake, fish catch and fish were diverse and did not differ among participants and respondents. Most of the changes reported were change of water colour to green. Abnormalities in fish included wounds, fish without eyes; some unique growths on fish and change of colour of fish from dark to pale were the most reported abnormalities. A significant reduction in the fish catch was also reported. All these changes were reported to have been noticed in the last three to five years and the situation was reported to be worsening. This period coincided with increase in the number of factories around the lake and growth in human population at the landing sites. In many respects, the local community has some knowledge about the problems resulting from waste disposal in the lake and its effects on them.

The effect and severity of pollutants on humans was reported in terms of itching of the body, bilharzia and diarrhea. The local community needs to be involved in addressing the problem of lake pollution and should participate in planning the interventions to enhance the productivity of fish in Lake Victoria and improvement of the Lake's health.

In Kenya, the lake water was observed to be green due to pollution emanating from Kisumu, Homabay and Suba districts. In contrast, the lake water was clear in Suba (Sindo and Ngeri village), a possible indication of less pollution or too toxic water. In Ngeri village in Kaksingiri, there are no industries but there are scattered households on the slopes surrounding the bay. There are several fish beaches/ landing sites in the area. Fishing is done in the waters near

the beaches with nets and lines. Fish predators seen by researchers and those reported by the local community are fish eagle, king fisher, egrets, cormonants, ibis, hammercock and otter. Water near the lake shore appeared to have more Nile perch than tilapia and there was a heavy demand for fish in the area. There was no complain about availability of fish and the Beach Management Unit (BMU) was functional. Some die-offs were reported in Remba island every July possibly due to volcanic activities (Rock becomes very hot). In Sindo area where the fish industry was active, dry fish waste was deposited into the lake, and flash waters transported pollutants from adjacent agricultural lands planted with maize and fruit trees during the rainy season and deposited them in the lake. In this area, many Omena (sardines) harboured tapeworms (*Ligula* spp). Tilapias with blocked, swollen and full urinary bladders were common in fish from Ngeri/ Sindo area possibly due to pollution, endocrine disruptors and parasites. A number of tilapia had pale livers that indicated presence of fats, degeneration or general impact of pollution.

Pollution was evident during the study as people were openly bathing, washing utensils, clothes, vehicles and bicycles in the lake. Droppings from cattle, goats, pigs, dogs, cats, chicken, ducks and various piscivorous birds (hammercock, kingfisher, cormonants, egrets, ibis, marabou stocks) were discharged directly into the lake. Evisceration of fish and dumping of offal back into the lake were common. Cleaning of eviscerated fish in the lake was also a common practice. Local people reported that dead fish with pale gills and deformed eyes were brought by some fishermen who were possibly using non-convectional fishing methods.

Microbial contamination and fish infection studies

Analysis of water samples that were collected from selected fish landing sites in Mwanza, showed that 78.6%, 35.7% and 85.7% of the samples were positive for TCC, TFC and TVC respectively (Table 1). The viable counts decreased from total coliforms to total faecal coliform. Previous studies in the same area (Mwanza gulf) reported similar results. The fishing grounds had remarkable bacterial counts in sediments and whole Nile perch guts while lake water counts were close to detection limits i.e. 0-20cfu/ml (Mhongole, 2009). Although in the same study Salmonella and *Vibrios spp* were detected each at 5% in Nile perch and lake water sample respectively, such pathogens as well as Cryptosporidia and Giardia were not detected in this study. Given that untreated domestic and industrial wastes were released directly into the lake, it can be concluded that point and non point sources of pollution are the main sources of microbial contamination of Lake Victoria's fish and water.

Table 1: Microbial contamination of water samples (n = 14) collected at various fish landing sites in Mwanza

Parameter	TCC	TFC	TVC
Positive samples (%)	78.6	35.7	85.7
Mean (cfu/ml)	2.5	2.7	3.7
Standard deviation (cfu/ml)	0.7	0.5	1.2
Median (cfu/ml)	2.2	2.5	3.8
Mode (cfu/ml)	2	2.5	3
Range (cfu/ml)	1.6 - 4	2.3 – 3.6	1 – 5.9
Total number of positive samples (n)	11	5	12

TCC = Total coliform count TFC = Total faecal coliform TVC = Total viable count

cfu = Log transformed Colony Forming Unit

Figure 1 shows the extent of microbial contamination in fish collected from different landing sites in Mwanza city. Overall, the findings demonstrate high surface and gill contamination by *E. coli* and *Staphylococcus spp*. Faecal pollution in water and handling of fish by fishermen as well as placing fish on contaminated landing sites were the possible sources of contamination observed.

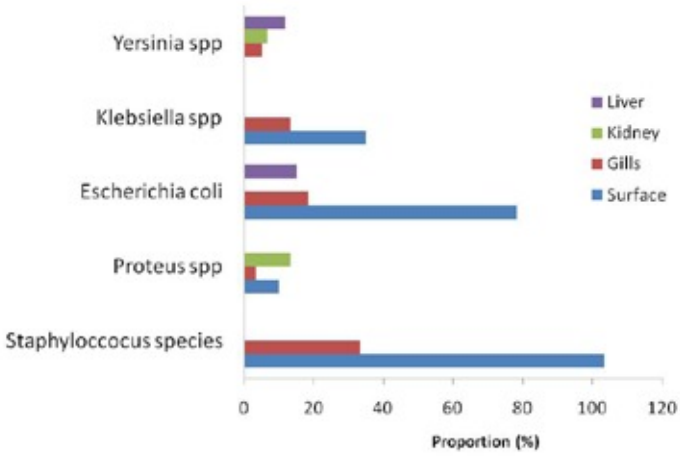

Figure 1: Microbial contamination of fish in Mwanza.

Microbial analysis showed that in Jinja, from, there was no significant difference in the microbial counts at the different sampling times ($P > 0.05$). Furthermore, there was no significant difference between the counts from the different sites for each category (APC, total coliforms, and *E. coli*) of counts except for the sites that experienced limited human activities. *Salmonella* spp were detected in only three samples obtained from Kakira drainage site, National Water and Sewerage Corporation treatment plant drainage, and Masese stone quarry drainage site. No *Vibrio spp* were detected.

The average counts for all the microbial categories in the shore line samples were significantly higher ($P<0.05$) than the offshore samples in all cases. These findings indicate dilution of the pollutants along the gradient. However, the dilution effect did not completely eliminate the organisms with increasing distance from the shoreline. Coliforms were also found in all the samples albeit with no significant differences among and between the sites. A significant percentage of these were *E. coli* indicating a possibility of fecal contamination. Therefore, there could have been co-pollution with other fecal-route pollutants such as endocrine disruptors (EDs) from human or agricultural activities hence the motivation for this study.

The bacterial counts from all the sites were higher than expected of good quality water for fish production. Although the *E. coli* count was significantly diluted offshore, the levels along the shore were above the acceptable levels on average and this is of major concern. There were also clear differences between the various sites ranging from the highest to the lowest counts (Table 2).

Table 3 shows the microbial counts in fish were higher than what was detected in the water for all microbial categories assessed and, as was expected, there was a decrease in numbers

from the total bacterial counts to total coliforms and *E. coli*. *Salmonella* spp were detected in surface washings and gills of one fish (3.8 %) while it was detected only in the intestines of two of the fish (7.7%). Although no *Vibrio spp* were detected in all the fish samples and water samples, the presence of the salmonella spp among the fish and water samples indicates that some of the fish are contaminated with potential pathogens of public health significance and measures are needed to curtail transmission to humans. In addition, it also indicates the risk of potential contamination with *Vibrio* in case of an outbreak.

Table 2: Comparison of average counts with ranges and standard deviation for water quality assessment of triplicate sampling for offshore and shoreline

	Shoreline			**Offshore (150 m offshore)**		
	APC	*T. coli*	*E. coli*	APC	*T. coli*	*E. coli*
Average	4.9×10^{8}	6.1×10^{6}	2.0×10^{4}	2.4×10^{5}	8.4×10^{3}	9.0×10^{-3}
Maximum	1.2×10^{9}	2.1×10^{7}	1.5×10^{5}	8.1×10^{5}	4.2×10^{4}	1.0×10^{-1}
Minimum	1.3×10^{6}	5.9×10^{4}	1.0×10^{-7}	4.1×10^{3}	6.1×10^{0}	0.0×10^{0}
St. Dev.	3.6×10^{8}	6.7×10^{6}	4.2×10^{4}	2.1×10^{5}	1.2×10^{4}	2.8×10^{-2}

Table 3: Bacterial counts for fish samples at Masese landing site in Uganda (average log 10 cfu/ml for surface washings and cfu/g for gills and intestines of triplicate counts)

Part of fish	**APC**	***T. coli***	***E. coli***
Surface washings	8.6	6.5	4.0
Gills	9.2	7.0	4.7
Intestines	9.1	6.9	4.4
Average	3.4×10^{9}	2.2×10^{8}	3.0×10^{6}
Maximum	4.3×10^{9}	2.8×10^{8}	5.2×10^{6}
Minimum	2.2×10^{9}	1.3×10^{8}	1.0×10^{6}
St Dev.	1.1×10^{9}	7.6×10^{7}	2.1×10^{6}

The counts in fish were far beyond the acceptable levels, thus revealing the extent of contamination and particularly very high *E. coli* levels beyond the acceptable limits. This further indicates the potential of contamination of fish with fecal matter that may also carry other chemicals such as EDs as a result of human or agricultural use of these materials and discharge into the lake. It is anticipated the analysis of the EDS and their effects on fish will greatly elucidate this further and shed more light on the importance of pollution control as one of the strategies for improving fish production in Lake Victoria.

Pathological findings in fish

The gross lesions observed in *Oreochromis niloticus* showed that the fish had hyperemia, wounds, ulcers on the lateral side of the body, opacity and no eyes, liver lesions, cystic bladder, skeletal deformities, atrophied testicles and kidney, degenerated ovaries, clear cysts in the testis, and change of colour of fish from dark to pale (Table 4). These lesions can be caused by variable aetiologies, including pollutants thus calling for further studies.

Table 4: Type of lesions observed in the fish samples

Pathological lesions	Number of fish with lesions
Hyperemia on the various parts of the body	7
Pale liver	2
Liver yellowish-white in color and friable	1
Grey spot on the liver	2
Hemorrhages on the surface of the liver	5
Liver dark red in color	1
Bile imbibitions in the liver	1
Cystic bladder	2
Hyperemia of the gills	1
Atrophied testicles and kidney	2
Opacity in the eye	6
Hemorrhages in the eye	3
Degenerated ovaries	3
Petechiae hemorrhages on the testis	4
Hemorrhages on the intestines	1
Grey patches on the stomach	3
Clear cysts in the testis	2
Dorsal fin starts from the middle of the back	1
Ulcers on the lateral side of the body	2

Fish parasites

Overall, the prevalence of parasite infection was 10% (n=80). Based on geographical distribution, the prevalence of parasite infection was 29% (n=21) in Dunga (Kisumu), and 4% (n=59) in fish sampled from Suba and Homa Bay. The parasites observed included *Procamallanus laevionchus, Camallanus, Acanthocephala* and unidentified nematode. Few haemoparasites, in particular *Trypanosome spp,* were also observed. Although all these parasites have been well documented (Stskopf, 1993), limited information is available for fish in Lake Victoria that also calls for further studies.

Conclusions

The findings of this study have confirmed similar status of pollution in Mwanza, Kisumu (Homabay and Suba) and Jinja in Tanzania, Kenya and Uganda respectively. Among pollutants reported and observed, some have the potential to cause endocrine disruption in fish and eventually impact on their productivity. These pollutants originate from point and non-point sources. Microbiological and pathological studies have provided findings that demonstrate:

i. The presence of microbial pathogens on the landing sites, water and fish.
ii. Contamination and infection of fish as well as pathological changes in fish.

The significance of these factors on progressive reduction of fish population and diversity in Lake Victoria need further studies.

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