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# Public Perceptions of Water Quality in the Lake Bunyonyi Sub-Catchment, Western Uganda

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**Abstract**

Lake Bunyonyi ecosystem plays vital roles in water resource conservancy and tourism. Nevertheless, the rapid increase in human population and the unrelenting human activities are threatening the values, functions, and ecological integrity of the lake. In this study, the public perceptions of drinking water quality and its health implications in the Lake Bunyonyi Sub-catchment, Western Uganda are presented. A closed-ended questionnaire was administered to 267 respondents living within one Kilometre away from the lake shores. Besides, observation and interview methods were used to complement data collected by the questionnaire method. Results indicate that the prominent activities around the lake are peasantry and small-scale businesses attributed to soil fertility and rural tourism. Despite the lake being a popular source of drinking water in the sub-catchment, the quality of its water suffers from diffuse pollution and little has been done to avert it. This study recommends regular surveillance and water quality testing to increase people's awareness of water quality. Besides, the local authorities should train people the alternative environmentally-friendly farming practices like afforestation with correct tree species and agro-forestry practices to increase vegetation cover and reduce soil erosion debris washed into the lake system. Environmental-friendly household water treatment methods (biosand filtration and solar disinfection) should be promoted to improve the quality of drinking water.

**Keywords**: Water quality, anthropogenic activities, solid water, household water treatment, Lake Bunyonyi.

## Introduction

Lakes play unique roles in meeting the water demands of communities for consumption, recreation and economic development. Thus, maintaining the natural hydrologic regime of the lakes is important for preserving these functions (Markogianni et al. 2016). Lothrop et al. (2015) noted that increased contaminant guideline exceedances in water supplies expose people, especially in rural areas to risks of long-term negative health outcomes, adding to their rural health disparities. Globally, the availability of freshwater is increasingly becoming limited due to pressure from human populations, intensive, industrialization, and raised water demands for industrial uses. Besides, the current figures indicate that more than 700 million people globally lack access to improved water sources (WHO and UNICEF 2014).

Access to safe drinking water sources in Uganda significantly increased from 54% in 2001 to 76% in 2015 because of high-level investment in the water sector by the government and other development partners. Nevertheless, the burden of waterborne diseases does not relent (WHO and UNICEF 2015). Most deaths in infants and children are caused by diarrhoeal disease as a result of unsafe drinking water. According to Nsubuga et al. (2014), the quality of water in lakes has been degraded as a result of human activities including discharges of wastewater containing degradable organic substances, nutrients, domestic effluent, and agricultural wastes. The discharge of untreated or partially treated waste from different sources such as domestic wastewater, stormwater, and agricultural runoff has effects on water quality and its end users (Murphy et al. 2017). Human influences like urbanization, agricultural activities, wastewater discharge and natural processes such as erosion could affect surface water quality to varying degrees. Nevertheless, the degree to which each factor contributes to water quality degradation and to what extent is not yet clear. In major water catchments in Uganda, destructive and exploitative human activities are evident (Murphy and Kitamirike 2019). The increased use of chemical fertilizers and pesticides in agricultural activities, and the current rate of soil erosion are severe; all impacting negatively on the lake ecosystems. These challenges are worsened by the growing population pressure, climate change, loss of wetlands, and deforestation mainly because of conversion to agricultural land (Murphy and Kitamirike 2019).

In the Kigezi sub-region, Lake Bunyonyi is a major source of water, and employment opportunities and a major tourist destination site in Western Uganda. Its watershed is a densely populated area with extensive subsistence farming. Nevertheless, unrelenting human activities such as the construction of cottages and hotel facilities, settlement, and overgrazing are threatening Lake Bunyonyi's values, functions, and ecological integrity. Therefore, the need to determine public awareness regarding drinking water quality and disease development and their adopted measures to reduce disease risks in the communities around Lake Bunyonyi is certainly very important. The study results are set to help in making informed decisions on the appropriate measures to militate against the lake's degradation and provide long-term reprieve for the other minor lakes of the Kigezi region facing similar challenges.

## Materials and Methods

### Study area

Data for the assessment of socio-economic activities were collected from villages surrounding Lake Bunyonyi. The lake is situated in the districts of Kabale and Rubanda, South-Western Uganda (Figure 1). It lies between 1.295° S and 29.91° E) with an altitude of 1,973 metres above sea level. The lake is long and narrow with a total surface area of 56 $km^2$. Its maximum depth is 40 m and is a major source of water for domestic use, agriculture, fishing and recreation (Kizza et al. 2017). The climate of the Lake Bunyonyi catchment is influenced by altitude and latitude. It is characterized by a bimodal rainfall distribution with the long rainy season occurring between March and May. The mean annual rainfall ranges from 800 mm to 1000 mm. The temperature in the lake catchment ranges from 23.7 °C in March to 24.8 °C in August (Tibihika et al. 2016). Lake Bunyonyi has no major inflows and the hills form the boundary of the lake catchment area. The lake outflow is a small stream from the northwest tip of the lake at a place commonly referred to as Heissesero in Muko Sub-County. This stream drains into Ruhuma swamp valley and along the Ruhezamyenda River to Mutanda and Mulehe lakes (Denny 1972).

Lake Bunyonyi catchment is shared by Rubanda and Kabale Districts with populations of 196,896 and 230,609 people, respectively (UBOS 2017a, b). The two districts are densely populated (286.5/$km^2$ for Rubanda and 422.4/$km^2$ for Kabale) and the lake catchment is predominantly rural with

7.7% of dwellers having no toilet facilities (UBOS 2017a, b). Extensive subsistence farming is the main economic activity and crops such as sweet potatoes, beans, sorghum, Irish potatoes, and vegetables are grown. In addition, the lake is a popular tourist destination point in Uganda and its rim and the islands harbour infrastructure developments such as campsites and magnificent hotels. On a small scale, fishing and aquaculture are carried out in the lake water (Kizza et al. 2017). Thus, the livelihood activities of the people in the lake catchment largely depend on the health of the lake ecosystem.

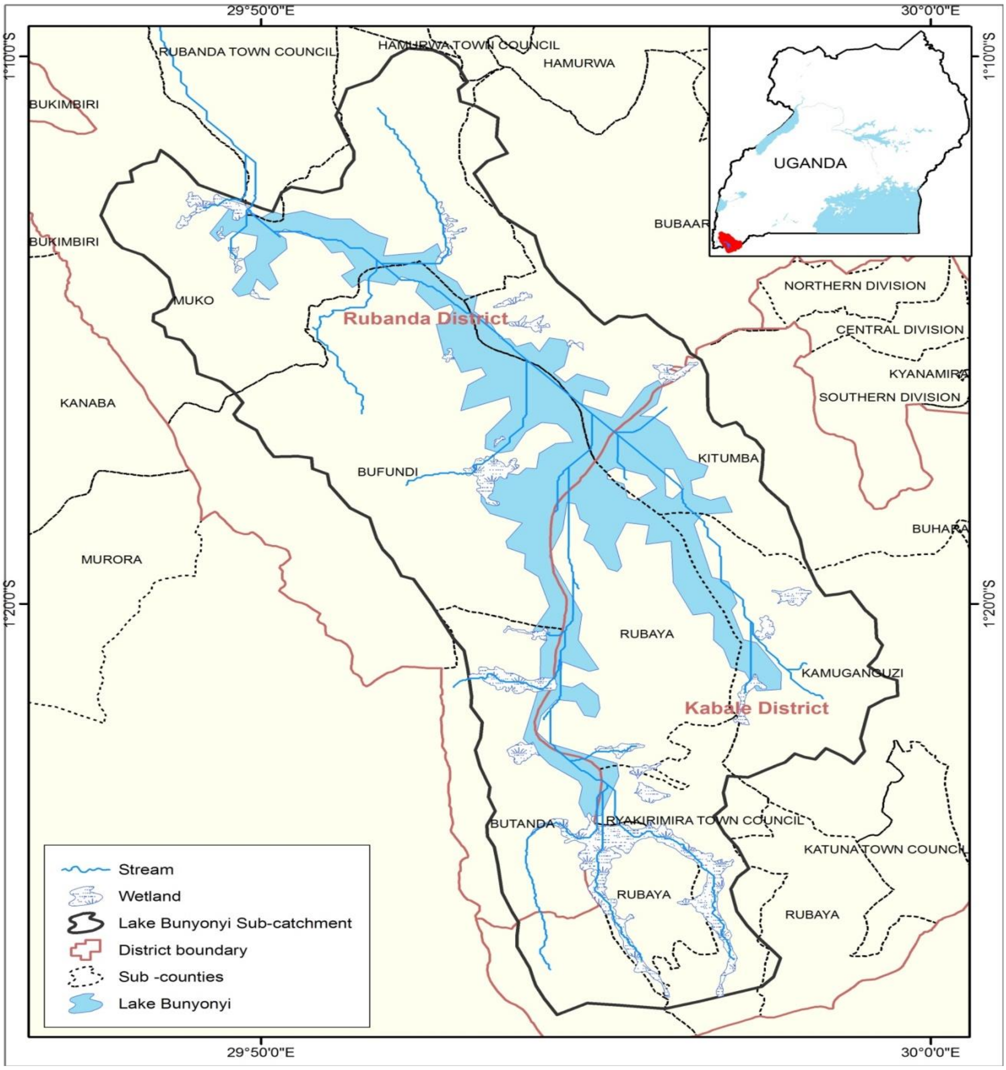


**Figure 1**: Location map of Lake Bunyonyi, Southwestern Uganda.

**Research design and sampling**

A descriptive research design utilizing both quantitative and qualitative approaches was used in data collection and analysis. A stratified random sampling method was used to obtain a sample of household residents within 2 km from the shores of upper, middle and lower Bunyonyi to which the questionnaire was administered to every 2nd household. Each member of the population has an equal chance of being included in the sample. Every possible sample of a given size had the same chance of being selected. In this study, the population of people living within 1 km from the shores of Lake Bunyonyi is not known. Therefore, the sample size was derived by computing the minimum sample size required for accuracy in estimating proportions by considering the standard normal deviation set at a 95% confidence level (1.96), the percentage picking a choice (50% = 0.5) and the confidence interval (0.06) using the formula developed by Ishmael (2014) as shown in Equation 1.

$$n = \frac{Z^2\,(P)\,(1-P)}{C^2} \quad 1$$

Where:

Z: standard normal deviation set at 95% confidence level, P = percentage picking a choice, and C= confidence interval.

$$n = \frac{1.96^2\,(0.5)\,(1-0.5)}{0.06^2} = 266.8 \quad 2$$

Therefore, the questionnaire was administered to 267 respondents.

## Data collection methods

A semi-structured questionnaire was used to collect data. The researcher also took a transect walk around the shore of the lake to establish what exactly happens around the lake. This transect walk was used to assess variables like trees planted around the lake, economic activities, the extent of deforestation, the slope of the land, and the extent of soil erosion among others. This was necessary for corroborating information got from key informants. The informal discussions with people who met along the route enriched and clarified various aspects of the lake's use.

## Data analysis

Data were coded and analyzed using Statistical Package for Social Sciences (SPSS) version 16.0 and MS Excel packages. Descriptive statistics such as frequency tables, cross-tabulations, and measures of central tendency and dispersion (means, medians, standard deviations, percentages and variances) were used. The various social and economic aspects of the households such as livelihood sources around the lake ecosystem and the measures proposed to mitigate the degradation of the Lake Bunyonyi ecosystem among others were analyzed using inferential statistics.

# Results

## Demographic information

The demographic information of the study area revealed that the majority (61%) of the respondents were males and middle-aged, i.e., 31–55 years old (Table 1). Collecting information from both sexes on the same issues provided gender perspectives and helped in assessing the reliability of the responses from the field study survey. The more young and middle-aged population, the more people engage in water quality and quantity monitoring since it is labour-intensive and requires people who are trained, flexible and energetic. In the Lake Bunyonyi sub-catchment, women were more involved in regular farm activities than men. This partially explains why female respondents were fewer than males. Also, the majority of respondents being in the middle age category implies that they have the energy to participate in the lake water quality monitoring when sensitized, trained and empowered. The education level of most respondents ranged from primary to advanced secondary level accounting for 64.8% (Table 1). Respondents with formal education were aware of the possible outcomes of drinking water from a contaminated source. The majority of the respondents (53.9 %) were married and 21% were living a single life. The justification for this distribution is that the field survey was targeting households headed by people aged 18 and above.

The most prominent economic activities were peasantry (48%) and small-scale businesses (33%) (Figure 2). The lake is a rural area and the land around the lake is fertile that attract farmers who also take advantage of irrigation. In addition, the lake attracts tourists with hotels (Plate 1). Small-scale businesses became the second prominent economic activity. Fishing is done on small scale (5%) and other activities mentioned were charcoal burning and tourism activities such as boat cruises, guided nature walks and adventures. Based on the one-year observations, it was realized that tourism was under-reported as one of the major activities in Lake Bunyonyi catchment since it employs the majority of the local youths especially those engaged in providing services like nature-guided walks, boat cruises, and working in the various campsites and hotels.

**Table 1**: Respondents' demographic information

| Questions/ statements | Responses | Frequency | Percent |
|---|---|---|---|
| Age of respondents | Above 56 | 71 | 26.6 |
| | 46–55 | 75 | 28.1 |
| | 31–45 | 68 | 25.5 |
| | 18–30 | 53 | 19.9 |
| | Total | 267 | 100.0 |
| Sex of respondents | Male | 163 | 61.0 |
| | Female | 104 | 39.0 |
| | Total | 267 | 100.0 |
| Level of education | Tertiary level | 33 | 12.4 |
| | Advanced secondary level | 43 | 16.1 |
| | Ordinary secondary level | 71 | 26.6 |
| | Primary level | 59 | 22.1 |
| | Not formally educated | 61 | 22.8 |
| | Total | 267 | 100.0 |
| Marital status | Single | 56 | 21.0 |
| | Married | 144 | 53.9 |
| | Divorced | 33 | 12.4 |
| | Widowed | 26 | 9.7 |
| | Widower | 8 | 3.0 |
| | Total | 267 | 100.0 |

Traditionally, Lake Bunyonyi and its environment used to be a source of drinking water, papyrus for thatching houses, fishing and a source of medicinal herbs amongst others. Nevertheless, the prominence of these activities has been changing in response to changes in demographic trends and the desire to enhance livelihood through business and the development of tourism-oriented infrastructures such as hotels and campsites and roads. This is supported by the visual observation of magnificent hotels and campsites during the study period (Plate 1).

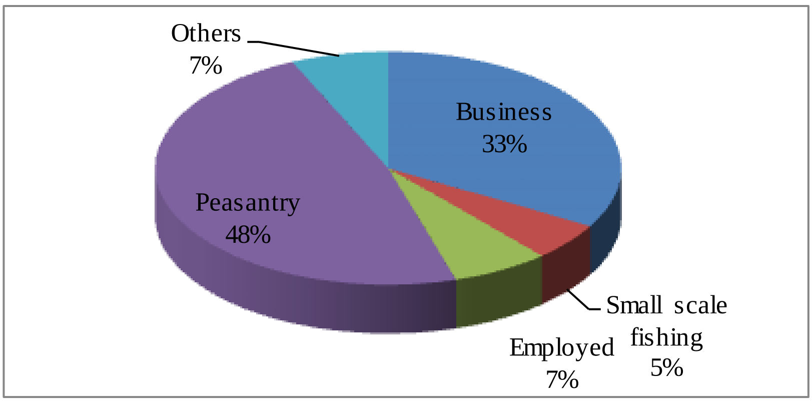


**Figure 2**: Economic activities conducted around Lake Bunyonyi area.

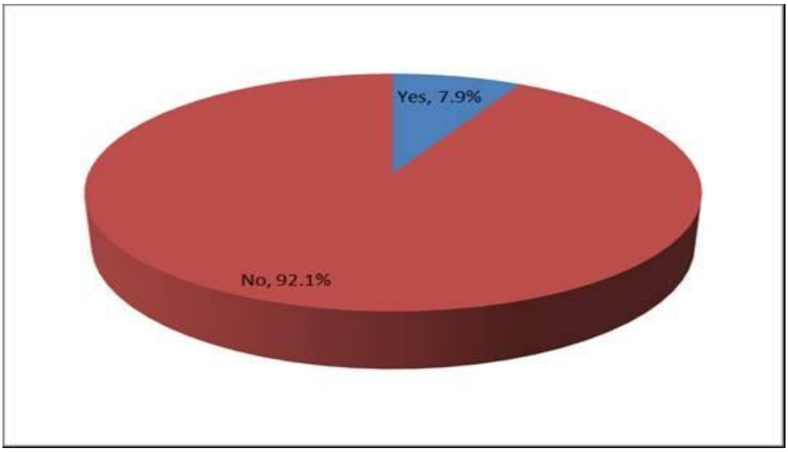


**Figure 3:** Pie Chart showing respondents' responses on diarrhoea disease incidences two weeks before study survey.


**Plate 1**: Photographs of some magnificent hotels and campsites adjacent to Lake Bunyonyi.

**Perceptions of water quality derived from Lake Bunyonyi**

The majority of respondents (95.5%) believed that the water quality of drinking water affects their healthy living standards (Table 2). The simple frequency analysis showed the respondents' knowledge about water quality giving a five-point like-type scale of information ranging from "strongly agree" to "strongly disagree". Respondents were asked to judge the quality of the water from Lake Bunyonyi based on the five sensory characteristics of drinking water. Results revealed that 53.2% of the respondents believed that taste of water derived from Lake Bunyonyi was good but the majority (75.6 %) said that the smell of the water was not good (Table 2). Likewise, most respondents reported that the water derived from the understudy is not clear and its colour is poor. Besides, most respondents (85.8%) were not sure whether the water derived from Lake Bunyonyi was safe for domestic use and drinking (Table 2).

**Household water treatment**

Boiling was found to be the most popular method of treating drinking water accounting for 62.2% while 28.5% reported not treating water for drinking (Table 3). The majority of the middle-aged respondents (i.e., 31–55 years of age) practised household water treatment more than the youngsters and the old (Tables 3 and 4). This is perhaps because middle-aged people are well versed in the health risks associated with drinking untreated people. Likewise, most respondents with formal education (52.3%) reported they were practising household water treatment than non-formally educated (15.7%) were purifying their drinking water compared to respondents with low levels of education (Table 4). Similarly, more married respondents (33.0%) were purifying their drinking water than the single, divorced, and widowed. Some respondents were not treating drinking water because; they believed their drinking water sources were safe (10.1%), water treatment is expensive (7.9%), treated water has a bad taste and smell (6%), and others reported they were used to drinking untreated water and nothing happens to them (Table 4).

**Table 2**: Perceptions of water quality in Lake Bunyonyi

| **Questions/ statements** | **Responses** | **Frequency** | **Percent** |
|---|---|---|---|
| Do you believe that water quality affects the health standards of people? | Yes | 255 | 95.5 |
| | No | 12 | 4.5 |
| | Total | 267 | 100.0 |
| Taste | Very good | 6 | 2.2 |
| | Good | 142 | 53.2 |
| | Fair | 92 | 34.5 |
| | Poor | 19 | 7.1 |
| | Very poor | 8 | 3.0 |
| | Total | 267 | 100.0 |
| Smell | Very good | 14 | 5.2 |
| | Good | 40 | 15.0 |
| | Fair | 94 | 35.2 |
| | Poor | 108 | 40.4 |
| | Very poor | 11 | 4.1 |
| | Total | 267 | 100.0 |
| Clarity | Very good | 1 | .4 |
| | Good | 7 | 2.6 |
| | Fair | 22 | 8.2 |
| | Poor | 111 | 41.6 |
| | Very poor | 126 | 47.2 |
| | Total | 267 | 100.0 |
| Colour | Very good | 6 | 2.2 |
| | Good | 38 | 14.2 |
| | Fair | 36 | 13.5 |
| | Poor | 142 | 53.2 |
| | Very poor | 45 | 16.9 |
| | Total | 267 | 100.0 |
| Safety of water | Strongly agree | 4 | 1.5 |
| | Agree | 29 | 10.9 |
| | Not sure | 229 | 85.8 |
| | Disagree | 5 | 1.9 |
| | Total | 267 | 100.0 |

**Table 3**: Cross-tab analysis of demographic characteristics (age, sex, level of education and marital status) to household water treatment

| Demographic | Profile | No (Frequency/Percentage) | Yes (Frequency/Percentage |
|---|---|---|---|
| Age | Above 56 | 25 (9.4%) | 46 (17.2%) |
| | 46–55 | 23 (8.6%) | 52 (19.5%) |
| | 31–45 | 25 (9.4%) | 43 (16.1%) |
| | 18–30 | 11 (4.1%) | 42 (15.7%) |
| Sex | Male | 57 (21.4%) | 106 (39.7%) |
| | Female | 27 (10.1%) | 77 (28.8%) |
| Level of education | Tertiary level | 6 (2.3%) | 27 (10.1%) |
| | Advanced level | 16 (6.0%) | 27 (10.1%) |
| | Ordinary level | 20 (7.5%) | 51 (19.1%) |
| | Primary level | 23 (8.6%) | 36 (13.5%) |
| | Not educated | 19 (7.1%) | 42 (15.7%) |
| Marital status | Single | 9 (3.4%) | 47 (17.6%) |
| | Married | 56 (21.0%) | 88 (33.0%) |
| | Divorced | 9 (3.4%) | 24 (9.0%) |
| | Widowed | 8 (3.0%) | 18 (6.7%) |
| | Widower | 2 (0.8%) | 6 (2.3%) |

**Table 4**: Response to household water treatment and health

| **Questions/ statements** | **Responses** | **Frequency** | **Percent** |
|---|---|---|---|
| Water treatment for drinking | No | 75 | 28.1 |
| | Yes | 192 | 71.9 |
| | Total | 267 | 100.0 |
| Method of water treatment | Boil | 166 | 62.2 |
| | Add chlorine tablets | 5 | 1.9 |
| | Bio-sand filtration | 2 | .7 |
| | Solar disinfection | 11 | 4.1 |
| | Use water guard | 7 | 2.6 |
| | Not applicable | 76 | 28.5 |
| | Total | 267 | 100.0 |
| Reasons for not purifying drinking water | It is expensive | 21 | 7.9 |
| | Bad taste and smell of treated water | 16 | 6.0 |
| | I believe water is safe from the source | 27 | 10.1 |
| | We are used to drinking untreated water | 10 | 3.7 |
| | Time-consuming | 1 | .4 |
| | Not Applicable | 192 | 71.9 |
| | Total | 267 | 100.0 |

**Waterborne disease incidents**

When asked whether their household has experienced diarrhoea cases in the last two weeks before the study survey, 92.1% of respondents reported no diarrhoea incidences, while 7.9% reported having had diarrhoea cases (Figure 3). Most married respondents (4.1 %) suffered diarrhoea disease in the last two weeks before the study survey (Table 5). Similarly, most respondents with no formal education reported the highest number of diarrhoea cases (4.9%) in the last two weeks before the study survey than other respondents (Table 5). As can be observed by frequencies cross-tabulated in Table 6, a significant association between diarrhoea incidences reported and household water treatment was recorded ($X^2$ (4, N = 267) = 20.577, p < 0.001). This implies that households drinking untreated water were more likely to suffer from diarrhoea than those one's water purifying drinking water. Similarly, Chi-square test (Table 7) revealed a significant relationship between the level of education and household water treatment ($X^2$ (1, N = 267) = 6.972, *p* = 0.008). This implies that people with formal education are more likely to treat their drinking water than those with no formal education.

**Table 5**: Cross-tab analysis of demographics characteristics (level of education and marital status) to reported diarrhoea cases in the last two weeks

| Demographic | Profile | Yes (Frequency/Percentage) | No (Frequency/Percentage |
|---|---|---|---|
| Level of education | Tertiary level | 0 (0%) | 33 (12.4%) |
| | Advanced level | 2 (0.8%) | 41 (15.4%) |
| | Ordinary level | 3 (1.1%) | 68 (25.5%) |
| | Primary level | 3 (1.1%) | 56 (21.0%) |
| | Not educated | 13 (4.9%) | 48 (18.0%) |
| Marital status | Single | 1 (0.4%) | 55 (20.6%) |
| | Married | 11 (4.1%) | 133 (49.8%) |
| | Divorced | 5 (1.9%) | 28 (10.5%) |
| | Widowed | 3 (1.1%) | 23 (8.6%) |
| | Widower | 1 (0.4%) | 7 (2.6%) |

**Table 6**: Cross-tabulation showing the relationship between the reported diarrhoea cases and household water treatment

**Chi-Square Tests**

| | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
|---|---|---|---|---|---|
| Pearson Chi-Square | 6.972[a] | 1 | 0.008 | | |
| Continuity Correction[b] | 5.739 | 1 | 0.017 | | |
| Likelihood ratio | 6.428 | 1 | 0.011 | | |
| Fisher's Exact Test | | | | 0.013 | 0.010 |
| Linear-by-Linear Association | 6.946 | 1 | 0.008 | | |
| N of Valid cases[b] | 267 | | | | |

a. 0 cells (.0%) have an expected count of less than 5. The minimum expected count is 6.61.
b. Computed only for a 2x2 table

**Table 7**: Cross-tabulation showing the relationship between the level of education and household water treatment

**Chi-Square Tests**

| | Value | df | Asymp. Sig. (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 20.577[a] | 4 | 0.000 |
| Likelihood Ratio | 19.143 | 4 | 0.001 |
| Linear-by-Linear Association | 13.649 | 1 | 0.000 |
| N of Valid cases | 267 | | |

a. 4 cells (40.0%) have an expected count of less than 5. The minimum expected count is 2.60.

**Sources of water contamination**

Soil erosion debris washed into the lake and wastewater discharge from hotels and campsites were found to be the major sources of the lake's surface water pollution, representing 42.7% and 29.6% of respondents, respectively (Table 8). Other reported sources of water contamination of the lake system include; domestic waste discharge, fertilizers and mature applied on crop farms around the lake, and oil spills from motorized boats. Although not part of our questionnaire, economic activities such as markets near the lake show form another point source of water contamination. For example, as can be seen at the Harutinda weekly market (Plate 2) where through our visual observations, it was noted that some food items, banana and pineapple peelings were seen dumped and decomposing at the lake periphery so revealing that a big portion had dropped into the lake system. The simple frequency analysis of the respondents' knowledge about the sources of water pollution gave to the five-point like-type scale of information ranging from "strongly agree" to "strongly disagree". When asked about whether people wash clothes among others directly from the lake, 85% of respondents agreed and strongly agreed (Table 8). In addition to washing clothes, we noted other cleaning activities (Plate 3) that included washing utensils and the animal intestines during slaughtering.

**Table 8**: Respondents' responses to sources of surface water contamination

| Questions/ statements | Responses | Frequency | Percent |
|---|---|---|---|
| Sources of pollution in the Lake | Wastewater discharge from hotels and campsites | 79 | 29.6 |
| | Herbicides and pesticides used on the farm | 15 | 5.6 |
| | Soil erosion debris washed into the lake | 114 | 42.7 |
| | Domestic waste discharged into the lake | 45 | 16.9 |
| | Oil spills from motorized boats | 14 | 5.2 |
| | Total | 267 | 100.0 |
| Occasionally, people wash clothes and other this directly from the lake | Strongly disagree | 5 | 1.9 |
| | Disagree | 15 | 5.6 |
| | Not sure | 20 | 7.5 |
| | Agree | 115 | 43.1 |
| | Strongly agree | 112 | 41.9 |
| | Total | 267 | 100.0 |
| The use of chemical fertilizers and pesticides can affect the water quality in streams, rivers and the lake | Strongly disagree | 13 | 4.9 |
| | Disagree | 16 | 6.0 |
| | Not sure | 90 | 33.7 |
| | Agree | 113 | 42.3 |
| | Strongly agree | 35 | 13.1 |
| | Total | 267 | 100.0 |

**Plate 2**: Photograph showing people in the Harutinda weekly market at the periphery of Lake Bunyonyi.


**Plate 3**: People wash utensils (A) and animal intestines (B) in the Lake water; and the decomposing waste from the slaughtered animals (pigs and goats) at the lake periphery (B). The intestinal waste was evident at the point that had parked the boat during the field study.

## Discussion

### Demographic characteristics of people in the lake catchment

This study involved respondents with the majority being middle-aged (31–55 years old) and there were more males (61%) than females. Collecting information from both sexes and different ages on the same issues provided gender perspectives and helped in assessing the reliability of the responses from the field survey. The more young and middle-aged population, the more people engaged in water quality monitoring since it is labour-intensive and requires people who are trained, flexible and energetic. In the Lake Bunyonyi sub-catchment, females are more involved in regular farm activities than men. This partially explains why female respondents were fewer than males as many of them were not found at home during the survey. Similarly, previous studies have reported a larger number of male participants than females. For instance, studies conducted in the USA and Ghana, have reported that the majority of participants as males in Oklahoma state (46%) and Wenchi Municipality (59 %) (Eck et al. 2019, Okumah et al. 2020). In addition, most respondents in the present study (77.2 %) had acquired primary-level education and above. The reported literacy rate is good and higher than 72%; the Uganda national literacy rate is as per UBOS (2018). Similar to our results, Mutambo (2018) reported high literacy rates of 85% in the Kiboga District of Uganda. The study survey results revealed that the majority of respondents were married.

**Socio-economic activities around Lake Bunyonyi**

The majority of respondents reported peasantry as the main source of household income and the major crops grown are; beans, potatoes, wheat, cabbages, sorghum and tomatoes. In Uganda, approximately 5.8 million households are engaged in farming while 69% of households derive income from subsistence farming (UBOS 2017). Similar results have been reported in other related studies. For instance, Mutambo (2018) reported that 89% of respondents' main source of income was farming whereas Tinzaara et al. (2021) and Nsubuga et al. (2021) reported 31 and 72%, respectively in Uganda. A reasonable proportion of respondents revealed they were involved in small-scale business activities. This is because tourists visiting Lake Bunyonyi have created a market for handicrafts and food items locally produced in the lake catchment. The present study findings are supported by Bires and Raj (2020) who found out that the socio-cultural and economic aspects of tourism impact indicators were found to significantly affect the economic livelihood outcome of Ethiopians with a 28.5% variance predicted.

Very few people were involved in fishing because of the limited fish species in the lake (Tibihika et al. 2016). The mudfish which used to be common in the lake area have become rare perhaps due drainage of swamps which are important breeding places. The limited fish species in Lake Bunyonyi can also be linked to Lake's limnological conditions. For instance, low water temperatures (18–23$^{o}$ C) in addition to being permanently stratified year-round (Green 1965, Beadle 1966) are not ideal conditions that favour the growth and survival of tropical fish species. The effects of stratification on fish are described in detail by Littlefair et al. (2020) and Singh et al. (2019).

**Household water treatment in the lake sub-catchment**

The survey results demonstrated that boiling was the most popular method of water treatment among the surveyed households in the lake sub-catchment. The belief that boiling is easy to use has been much emphasized by the Ministry of Health through the Village Health Teams (VHTs) to improve access to safe drinking water in the rural areas of Uganda. Similar results have been reported (Kausar et al. 2011, Saturday et al. 2016, Khalid et al. 2018) in their surveys where most respondents were using boiled water for drinking. While it has been frequently reported that many people in Uganda use boiled water for drinking (Saturday et al. 2016), in neighbouring Kenya (Sreenivasan et al. 2015), hypochlorite (WaterGuard) is widely used. According to Clasen et al. (2008), the boiling method can be the most effective to kill pathogens in water including bacterial spores and protozoa when properly handled. The method is preferred because it is an easy-to-use and inexpensive way to improve drinking water (Sodha et al. 2011). The use of chlorine tablets and WaterGuard for water treatment was not popular in the study area perhaps because of limited awareness about their ease of use and suitability. Besides, chlorine tablets and hypochlorite are not readily available in markets and are a bit costly for the local poor people.

**People's Perceptions of the quality of water from Lake Bunyonyi**

The majority of respondents revealed that the taste of water was good while others believed that the water derived from the Lake is bad. In other related studies, Khalid et al.

(2018) reported that most respondents agreed that the smell of the water was not good. Smell is the highest-rated predictor of pollution and influences the perception of water quality (Dinius 1981). According to Abraham et al. (2016), the unpleasant smell from a lake may indicate uncleanness and therefore of low quality. It is understood that some people view smell as an index of the severity of water contamination. In such circumstances, the public tends to perceive these water resources as wastewater disposal channels (Abraham et al. 2016). Based on our observations, the smell of the lake water was caused by pollution. This is so because; the smell was particular to some points with observable indicators of water contamination. The clarity and colour of water influence people's perceptions to judge whether the quality of water in a lake is acceptable and hence fit for human consumption (Smith and Davies-Colley, 1992). Smith and Davies-Colley (1992) found that visual factors such as colour and clarity are vital in determining water quality as it suggests to users, the possibility of toxicity. For instance, when lots of waste materials are dumped into a lake and the water is discoloured, some bad odour starts to come out. In such a situation, people will start to judge the lake as being contaminated.

**Surface water contamination in the lake sub-catchment**

Most respondents reported soil erosion debris washed into the lake and wastewater discharge from hotels and campsites as the sources of the lake's water contamination pollution. For instance, during the rainy season, the remnants of fertilizers and manure are easily washed with other materials into the lake system through surface runoff. This partly explains high nutrient concentration levels (nitrates and phosphates) in the lake water system during the rainy season. Besides, animal rearing (livestock) is observed in the sub-catchment and produces dung which when washed into the lake system contributes to bacterial (*E. coli* and Enterococci) and nutrient contamination, in addition to soil erosion debris and wastewater discharge introduced into the lake system. Similarly, the observed dumping of remnants from the brewing point of the local beer popularly known as '*Obushera bw'ahagyenzi*' at the Mugyera trading centre was found to be one of the major sources of contamination of the lake water section adjacent. Pesticides such as herbicides applied to the gardens in the lake's neighbourhood, and oil spills from motorized boats were other reported sources of water contamination although the present study was unable to quantify the magnitude of their effects. Establishing crop farms very close to the water sources puts them at risk of chemical contamination especially when chemical fertilizers, organic manure and pesticides applied on the farm end up in the lake water system via runoff water after heavy rains. Constructing toilet facilities in very close proximity to the water source (< 20 meters) puts it at risk of faecal contamination. For instance, Sivaraja and Nagarajan (2014) found out that River Cauvery in India was loaded with coliform bacteria attributable to raw sewage.

**Conclusion and Recommendations**

Lake Bunyonyi is most people's source of water and people were not satisfied with its quality. The survey results also provided evidence of faecal water contamination since some respondents reported diarrhoea cases and some latrine facilities were constructed very close to lakeshores. The study, therefore, recommends that regular water quality monitoring studies be conducted to monitor water quality and advice on the best practices for lake water quality management. While most people earn a living from small-scale businesses and peasantry, their reported waste disposal methods around the lake are not appropriate. For instance, waste disposed of at the free space near as most respondents stated ends up in the lake hence causing pollution. The local authorities should put stringent measures to curb poor waste disposal practices around the lake understudy. Soil erosion debris and wastewater discharge are the foremost causes of water contamination in the lake understudy. To this effect, the local authorities should train people the alternative environmentally-friendly farming practices like afforestation with correct tree species and agro-forestry practices to increase vegetation cover and reduce soil erosion debris washed into the lake system. Although the boiling method of household water treatment is not environmentally friendly due to fuelwood, it was found to be the most popular method of household water treatment methods of all the methods. Therefore, the need to promote water treatment methods such as biosand filtration and solar disinfection is absolute since the methods are cheap to use and environmentally friendly.

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**Authors' contributions**

AS conceived and designed the study, collected and analyzed data, and drafted the manuscript: TJL contributed to the conception and design of the study, and assisted in data interpretation and revision of the manuscript for intellectual content. SP contributed to the conception and design of the study and assisted in data interpretation and revision of the manuscript for intellectual content. SK contributed and assisted in data interpretation and revision of the manuscript for intellectual content. JK contributed and assisted in the revision of the manuscript for intellectual content. All the authors read and approved the final manuscript for publication.

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**Data availability**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Declarations**

**Ethics approval and consent to participate**

This study was conducted according to the guidelines laid down in the Uganda National Council for Science and Technology (UNCST) and all procedures involving research study were approved by the Higher Degrees Committee (HDC) for the College of Natural and Applied Sciences. University of Dar es Salaam. Additionally, written informed consent was obtained from all participants.

**Competing interests**

The authors declare that they have no competing interests.

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