Water Quality in Selected Water Springs in Banda, Kampala-Uganda.

Twalibu J Nzanzu[a,*], Joshua Barasa[a], Nanyonga Sarah Kiwanuka[a], JeanBosco Binenwa[b]

[a] *Department of Chemistry, Faculty of Science, Kyambogo University, P. O. Box 1, Kyambogo, Uganda.*
[b] *Graduate School, Kampala University P.O Box 25454 Kampala Uganda.*

Abstract

Background

Groundwater is the main source of water for drinking and other domestic use for the people of Banda. The main objective was to assess water quality in selected springs in Banda in the Kampala district. The specific objectives were to determine the pH, electroconductivity, alkalinity, turbidity, total dissolved solids, mineral and heavy metal content of the water samples as well as their fecal coliform counts.

Methodology

Two samples were collected from each spring at an interval of one week. Electroconductivity and pH measurements were done on-site using a conductivity meter and a digital pH meter respectively. Alkalinity and chlorine content was determined by titration, total dissolved solids by the gravimetric method, and turbidity by use of a turbidity meter while Atomic Absorption Spectroscopy was used for both mineral and heavy metal analysis. Fecal coliforms were enumerated using the membrane filtration method. Minerals assessed were calcium, potassium, sodium, chlorine, and magnesium while lead, cadmium, copper, and arsenic were the heavy metals of interest.

Results

Results showed the following concentration ranges: pH (4.71-6.26), electro conductivity (218.80-621.00 μS/cm), alkalinity (10.35-60.40 mg/L), total dissolved solids (111.90-323.20 mg/L), turbidity (2-3 FTU), Sodium (16.11-34.45mg/L), Chlorine (17.73-49.25 mg/L), Calcium (4.81-20.05 mg/L), Magnesium (2.50-4.87 mg/L), Potassium (4.05-11.85 mg/L) and Lead (0.17-0.24 mg/L), Copper (1.69-2.66 mg/L), Cadmium (0.02-0.08 mg/L), Arsenic (0.005-0.01 mg/L). Fecal coliforms ranged between 1150 and 2700 colony forming units/100ml.

Conclusion

From analyses carried out, spring water from Banda is chemically and microbiologically unsuitable for the drinking-water purpose except after some form of treatment.

Recommendations

National Water and Sewerage Cooperation should take urgent action by carrying out more research on all water springs in this area.

Residents of this area should be encouraged to use tap water than spring water until further analyses are carried out.

Keywords: Banda, groundwater, quality, drinking water, minerals, heavy metals, fecal coliforms,
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1. Background

Ground and surface water quality has always been a very important aspect on the global scale and has presented several implications for the inhabitants of urban areas. Today, surface water is most vulnerable to pollution due to its easy accessibility for the disposal of pollutants and wastewater (Jarvie *et al.,* 2018). Worldwide, surface water quality is governed by complex anthropogenic activities and natural processes (Ravichandran, 2003). These include weathering, erosion, hydrological features, climate change, industrial activities, agricultural land use, sewage discharge, and human exploitation of water resources (Arain *et al.,* 2008; Liao *et al.,* 2008; Mahvi *et al;* 2005).

The rapid urbanization in developing countries like Uganda has led to a massive increase in human settlements which is growing faster than the rate at which the drainage network is being enhanced causing a mismatch between service and urbanization (Hope, 2022). This leads to health, social and economic problems that affect urban settlers, especially the poor. The excreta disposal facilities and solid waste collection points IN Banda are largely unimproved leading to groundwater pollution and unhygienic conditions.

Water quality assessment is a helpful tool not only to evaluate the impacts of pollution sources but also to ensure efficient management of water resources (Strobl, 2008). Human Adenoviruses F and G have been detected in spring water used for domestic purposes in Uganda. The problem is that in the overbuilt patchwork of brick and scrap metal houses that make up the slums in Banda, there is no easy way to empty the pit latrines. The roads are poor and even when the latrines fill up, sewage removal trucks cannot navigate the narrow dirt and mud streets, and most people cannot afford them anyway. As a result, pit latrines that eventually fill up overflow thus contaminating both surface and groundwater.

The widespread of pathogenic micro-organisms poses a potential public health risk and underlines the need for assessment of water quality in selected springs in Banda. This need also stems from the fact that fresh water will be a scarce resource in the future (Alberto *et al.*, 2001; Qadir *et al.,* 2008; Singh *et al.,* 2004). The quality of water is determined by assessing three classes of attributes: biological, chemical, and physical (Hassan Omer, 2020). There are standards of water quality set for each of these three classes of attributes. Given these standards, stream and groundwater supplies should be of high quality (Alberto *et al.,* 2001).

Banda is a low-lying area (mostly a reclaimed wetland) with a very high ground water table. It is largely unplanned with a lack of basic services, poor road access, and deplorable housing. Banda has one of the highest population growth rates in Kampala, based on the fact that it is both a residential and business corridor with students of Kyambogo College School and Kyambogo University its annual average rate of 9.6% more than twice the city's average growth rate of 3.7% (Ssemugabo *et al.,* 2020). It is the most deprived slum area in Kampala officially housing over 300,000-400,000 people (Lule and Jeff, 2011). The majority of the population is grossly youth and elderly and cannot afford tap water from National Water and Sewerage Corporation (NWSC). As a result, they resort to using spring water which could be contaminated owing to their poor waste disposal habits. Poverty aside, most people in the slums are disadvantaged and therefore have little knowledge of the dangers of poor sanitation and hygiene.

In a study carried out by Ssemugabo and others (2020), it was found that 68% of people dispose of their waste in drainage channels because they lack space for dumping. The other method of disposal practiced by 22% of the population was open space dumping which allows the waste (Ssemugabo e*t al.,* 2020)s to end up contaminating water sources. This study aimed at assessing the quality of water from selected springs the results of which could help point to the probable pollution sources by determining pH, electroconductivity, alkalinity, turbidity, total dissolved solids, total coliform; concentration of Calcium,

*Corresponding author.
Email address: nzanzujoshua@gmail.com (Twalibu J Nzanzu)

Potassium, Sodium, Chlorine, and Magnesium; and the heavy metal concentrations particularly Lead, Cadmium, Copper, and Arsenic in the water in Banda springs.

Banda is found in the Nakawa division, Kampala district. It has 23 parishes and 723 villages. Parishes in Nakawa Division Subcounty namely; Banda Bogolobi Bukoto I Bukoto Ii Butabika I.t.e.k Kiswa Kiwatule Kyambogo Kyanja Luzira Luzira Prisons Mbuya I Mbuya Ii Mutungo Nabisunsa Naguru I Naguru Ii Nakawa Nakawa Institutions and Ntinda U.p.k Upper Estate.

Banda is in Kampala district in the Nakawa Division sub-county. It is comprised of the following parishes; Acholi Quarters, B1 A, B1 B, B1 C, B10 A, B10 B, B11 A, B11 B, B2 A, B2 B, B3 A, B3 B, B3 C, B3 D, B3 E, B4 A, B4 B, B5 A, B5 B, B6 A, B6 B, B7 A, B7 B, B8 A, B8 B, B8 C, B9 A, B9 B, B9 C, Banda, Mbalwa and Zone B. This research was guided by the following objectives; to determine the pH, electroconductivity, alkalinity, turbidity, total dissolved solids, mineral, and heavy metal content, and fecal coliform counts of collected samples.

The major sources of water for residents of most parts are springs because they are free and maintain flow all year round.

2. Materials and Methods

Sampling

A total of 12 water samples were collected from six sampling sites (springs) in Banda. Samples were obtained from at least two springs in the parishes where they were available. The sampling sites were chosen by random sampling method. Samples were collected over one week from April 2021. Measurements of pH and electro-conductivity were done on-site. For the remaining analyses, samples were placed in sterile sampling bottles and immediately transported to the chemistry laboratory of the Uganda Industrial Research Institute.

Chemical Analysis

Determination of pH

The pH was determined using a digital pH meter. The meter was calibrated with pH 4 and 7 using standard buffer solutions according to the manufacturer's instructions. For each sample, analysis was done on-site using two replicas and the electrode was always rinsed with distilled water between samples.

Determination of Alkalinity

Alkalinity was determined by titration. 30.0 mL of each water sample was titrated with standard sulfuric acid using methyl orange as an indicator. The endpoint was a change in color from yellow to orange. This was done in three replicas and the average titre value was calculated. Alkalinity was then calculated from;

Alkalinity as CaCO3 (mg/L) = Volume of H2SO4 X Normality of H2SO4 X 50 X 1000

The volume of a sample taken for titration

Determination of Electrical Conductivity

This was measured using a conductivity meter. A standard conductivity solution of 0.01M potassium chloride was first prepared in the laboratory and used to calibrate the conductivity meter. At different times, the electrode was dipped into each water sample and placed in a clean glass beaker. The device gave a direct measurement of that particular sample's conductivity.

Determination of Total Dissolved Solids

1.0 mL of each sample was measured using a calibrated measuring cylinder. This was filtered before being transferred into a pre-weighed evaporating dish. Each sample was then evaporated in a steam bath after which it was dried in an oven at a temperature of 200oC. After complete drying, samples were desiccated to allow them cool and achieve a constant weight. The weight of each evaporating dish containing the sample residues was taken using an electronic balance. Total dissolved solids were then obtained by subtraction.

Determination of the water's turbidity

This was determined using a turbidity meter. The meter was first calibrated using a standard solution. Each water sample was placed into the sample cells. The turbidity meter gave a direct reading of the sample's turbidity. Analysis was done in three replicates.

Determination of Chlorine content in the water

Chlorine was determined by titration. 20.0 mL of each water sample were pipetted into a conical flask and titrated with 0.02N silver nitrate solution using potassium chromate as an indicator. Titration continued until when the solution changed from yellow to brick red marking the endpoint. For each sample, titration was done on three replicas while noting the amount of silver nitrate solution consumed. The average titre value was calculated and noted as V. A blank was also titrated and the titre value was noted as VB. the chlorine content of each water sample was calculated from;

Chlorine (mg/L) = (V-VB) X Normality of Silver nitrate X 35.45 X 1000

The volume of a sample taken

Mineral and Heavy Metal Analysis

Analysis of calcium (Ca), Iron (Fe), potassium (K), sodium (Na), magnesium (Mg), lead (Pb), cadmium (Cd), copper (Cu), and mercury (Hg) was carried out using Atomic Absorption Spectroscopy (AAS).

Sample Digestion procedure

To ensure the removal of organic impurities from the samples and thus prevent interference in analysis, the samples were digested with concentrated nitric acid (HNO3). 5.0 mL of concentrated nitric acid was added to 100.0 mL of sampled spring water and placed in a 250.0 mL conical flask. The mixture was evaporated to a volume of 20.0 mL. After cooling the flask, 5.0mL of concentrated nitric acid was again added followed by heating on a hot plate. The digestion continued until only 10.0 mL were left. These were then filtered and diluted with distilled water into a 100.0 mL volumetric flask and stored in the refrigerator awaiting analysis.

Sample Analysis

The digested water samples were analyzed for the presence of the above-mentioned minerals and heavy metals using the Atomic Absorption Spectrophotometer. The calibration plot method was used for analysis. Air acetylene was the flame used together with the hallow cathode lamp of the corresponding element. Heavy metals were determined at wavelengths 283.3 nm, 228.8 nm, 324.8 nm, and 194.2 nm for Pb, Cd, Cu, and Hg respectively. Calcium, iron, potassium, sodium, and Magnesium were analyzed at wavelengths of 422.7 nm, 248.3 nm, 766.5 nm, 589.0 nm, and 285.2 nm respectively. The digested samples were analyzed in triplicates with the average concentration being displayed in mg/L by the machine.

Test for Fecal Coliforms

This was done using the membrane filtration method. Water samples were homogenized by vigorous shaking. 250.0 mL of each water sample was filtered through a sterile 0.45-micron membrane filter paper. The filter paper was then placed into a nutrient broth tube followed by incubation at 37^{o}C for 24 hours. After incubation, 1.0 mL of the nutrient broth was inoculated into a MacConkey broth tube. This was incubated at 37oC for 48 hours. There was gas production so the broth was streaked onto a Petri dish having MacConkey agar which was then incubated at 37^{o}C for 24 hours. The pink-red colonies observed were counted and the results were calculated and reported as the number of fecal coliforms per 100mls of water.

3. Data Analysis

Data collected were subjected to analysis using SPSS version 23 to determine if there were significant differences among the means.

4. Results and Discussion

Hydro Chemical Properties of Spring Water in Banda

pH

Values for pH ranged between 4.70 and 6.25. Water from spring 4 had the highest pH while water from spring 6 presented the lowest pH among all the assessed spring water samples.

According to the Environmental Protection Agency (2021), the noticeable effects of a pH less than 6.5 include a bitter metallic taste and corrosion. On the other hand, water with a pH greater than 8.5 will present a slippery feeling, soda-like taste, and deposits.

Implying none of the sampled spring water had a pH within permissible limits set by the Environmental Protection Agency and as such can be

Table 1: Hydro Chemical Properties of Spring Water

Spring Name		pH	Electrical Conductivity (μS/cm)	Alkalinity (mg/L)	Total Dissolved Solids (mg/L)	Turbidity (FTU)
Spring (AQ1)	**1**	5.15±0.06^{a}	218.50±3.00^{a}	31.20±1.12^{a}	111.90±3.74^{a}	2
Spring (AQ2)	**2**	5.40±0.11^{b}	286.50±4.43^{b}	33.15±0.19^{b}	146.75±1.06^{b}	2
Spring (BII)	**3**	6.10±0.11^{c}	365.50±6.35^{c}	58.50±0.14^{c}	187.88±1.60^{c}	3
Spring (BII)	**4**	6.25±0.06^{c}	358.00±1.15^{c}	60.40±0.11^{d}	184.40±1.55^{c}	3
Spring (MBIII)	**5**	4.85±0.06^{d}	583.00±2.31^{d}	22.25±0.40^{e}	303.88±1.02^{d}	3
Spring (MBIII)	**6**	4.70±0.11^{d}	621.00±1.15^{e}	10.35±0.20^{f}	323.20±1.45^{e}	3

Values in the same column with the same superscript are not significantly different ($p<0.05$)
Note; AQI, BII, MBIII representing, Acholi Quarter, Banda (PI, PII and PII) and Mbala respectively

deemed acidic whose cause could be ranging from chemical pollution from industrial operations, individuals, and communities which chemicals can enter the water through illegal discharges or after inadequate wastewater treatment since Banda has poor waste.

The higher pH of water from parish II could be due to the topography of Banda as it's composed of mainly clay soils with poor aeration and low infiltration capacity. And due to the rampant floods in the area, the rainwater that could contain pH-lowering ions stays on the surface rather than infiltrating into groundwater.

Electro Conductivity

Values for electroconductivity were in the range of 218.50 and 621.00 μS/cm. Water from spring 6 had the highest value of electroconductivity (621.00 μS/cm) while water from spring 1 had the least value (218.50 μS/cm). All the assessed water samples were within permissible limits for drinking water according to the California State Water Resources Control Board Division of Drinking Water which established a secondary maximum contaminant level of 900μS/cm for electroconductivity in water.

Total Dissolved Solids (TDS)

Total dissolved solids ranged from 111.90 to 323.20 mg/L with water from spring 6 having the highest value while water from spring 1 had the least.

In a study conducted by the World Health Organization (WHO, 2011), the palatability of drinking water was rated by a panel of tasters about total dissolved solids' levels as follows: excellent, less than 300 mg/ litre, good between 300 and 600 mg/ litre, fair between 600 and 900 mg/ litre, poor between 900 and 1,200 mg/ litre and unacceptable when greater than 1,200 mg/ litre. Aesthetically, water from the sampled springs in Banda I and II can be considered excellent because their TDS values are below 300 mg/ litre while water from springs in Banda III can be deemed of good quality as it falls in the range of 300 and 600 mg/ litre.

However, while TDS itself may only be an aesthetic and technical factor, a high concentration of total dissolved solids is an indicator that harmful contaminants such as sulfate, bromide, lead, and arsenic can also be present in water. This is especially true when excessive dissolved solids are added to the water as a result of human pollution through runoff and wastewater discharges which is typical in the case of Acholi Quarters

Alkalinity

Levels of alkalinity were in the range of 10.35 and 60.40 mg/L with water from spring 4 presenting the highest value while water from spring 6 had the least.

This implies that spring 4 water has a better buffer capacity than water from the other springs while spring 6 is poorly buffered due to its low alkalinity and is therefore prone to pH reduction. Alkalinity not only helps regulate the pH of water but also its metal content.

Turbidity

Values for turbidity were 2FTU (Formazin Turbidity Units) for spring water sampled from the Mbalwa parish while all the other samples from the remaining two parishes registered a turbidity level of 3FTU. The turbidity levels in the water samples were in agreement with the set standard which stipulates a maximum of 5FTU/NTU for the case of drinking water (EPA,2019).

Mineral Content of Spring Water from Banda

Chlorine

The concentration of chlorine in the water samples ranged between 17.73 and 49.25 mg/L with water from spring 4 having the highest value while water from spring 5 had the lowest level. Chlorine levels in unpolluted waters are often below 10.0 mg/L and sometimes below 1.0 mg/L.

The very high levels of chlorine in water can be attributed to possible pollution of spring water especially due to poor domestic and industrial waste disposal in Banda. No health-based guideline value is proposed for chlorine in drinking water. However, the Environmental Protection Agency (EPA) set a secondary maximum contaminant limit of 250.0 mg/L. This is in agreement with the World Health Organization (WHO) indicative recommended value for chlorine in drinking water. The water samples, therefore, were within permissible limits as far as this guideline is concerned (Drinking Water Contaminants, 2019)

Sodium

Levels of sodium in the water samples ranged from 16.11 to 34.45 mg/L. Spring 4 had the highest value while spring 6 had the least concentration. The ambient concentration of sodium in groundwater is only a few mg/litre (less than ten) and an increase in sodium in groundwater above ambient or natural levels may indicate pollution from the point or non-point sources. This implies that these high levels indicate that water in these springs is polluted which pollution is most likely from wastewater infiltrating from onsite sanitation systems like pit latrines and septic tanks. The Canadian drinking water quality objective for sodium is an aesthetic objective that stipulates a limit of 200.0mg/L. This is because concentrations above this limit can be tasted by people who utilize such water yet any taste alterations are simply undesirable.

Calcium

Calcium concentration in the spring water was in the range of 4.81 to 20.05 mg/L with spring 4 being the highest concentration while spring 6 was the lowest. Calcium is normally below 15mg/L in fresh groundwater. However, it can be as high as 100.0 mg/L in carbonate-rich rocks. Water samples from springs 3 and 4 exceeded the 15 mg/L and water from these springs can be deemed of good quality and can be classified as soft water since it does not exceed the 75mg/L limit for hardness.

Magnesium

The magnesium content of the spring water ranged from 2.50 to 4.87 mg/L with spring 4 having the highest concentration while spring 5 had the lowest (Arain *et al.,* 2008). Normally, magnesium ranges between 1 and 50 mg/L depending upon the rock type from which it originates. Magnesium has no established standard. It is an essential element for both plant and animal nutrition. However, elevated levels (in combination with calcium) can cause incrustation on utensils and consume soap lather. The magnesium content of water from the assessed springs in Banda is low thus the water is not considered hard (Drinking Water Contaminants, 2019)

Potassium

Levels of potassium in the water samples ranged between 4.05 and 11.85 mg/L. Spring 4

Table 2: Mineral Content of Spring Water in Banda

Spring name	Chlorine (mg/L)	Sodium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)
Spring 1(B1)	$24.82{\pm}0.02^{a}$	$18.51{\pm}0.17^{a}$	$12.02{\pm}0.01^{a}$	$3.79{\pm}0.14^{a}$	$6.66{\pm}0.03^{a}$
Spring 2(BI)	$26.24{\pm}0.01^{b}$	$21.80{\pm}0.05^{b}$	$12.84{\pm}0.02^{a}$	$4.11{\pm}0.02^{a}$	$7.80{\pm}0.02^{b}$
Spring 3(B1I)	$46.08{\pm}0.05^{c}$	$29.83{\pm}0.07^{c}$	$19.62{\pm}0.01^{b}$	$4.82{\pm}0.01^{b}$	$10.25{\pm}0.01^{c}$
Spring 4(B1I)	$49.25{\pm}0.03^{d}$	$34.45{\pm}0.04^{d}$	$20.05{\pm}0.02^{c}$	$4.87{\pm}0.02^{b}$	$11.85{\pm}0.18^{d}$
Spring 5(B1II)	$17.73{\pm}0.01^{e}$	$17.89{\pm}0.06^{a}$	$5.20{\pm}0.02^{d}$	$2.50{\pm}0.09^{c}$	$4.57{\pm}0.06^{e}$
Spring 6(B1II)	$21.28{\pm}0.01^{f}$	$16.11{\pm}0.02^{e}$	$4.81{\pm}0.01^{e}$	$2.99{\pm}0.07^{c}$	$4.05{\pm}0.04^{e}$

Values in the same column with the same superscript are not significantly different ($p<0.05$).

presented the highest concentration while the water from spring 6 was the least. Potassium's concentration in natural fresh waters is generally less than 10 mg/L (EPA). Potassium levels for spring water samples from parishes I and III were in agreement with this limit. However, the concentration of potassium in water from both springs in Banda parish III was above 10 mg/L. This could point to some form of pollution which increased potassium levels in the groundwater sources from this parish. There are no health-based drinking water standards for potassium and neither does it have a secondary drinking water standard. This is because potassium is an essential element and is seldom if ever, found in drinking water at levels that could be a concern for healthy humans (WHO). Therefore, potassium levels in water from springs in Mbalwa parish are no cause for worry.

Heavy Metal Concentrations in Spring Water from Banda

Lead

The concentration of lead in the water samples ranged between 0.17 ppm in water from spring 4 in Banda parish II and 0.24 ppm in water from spring 5 in Banda parish III. The WHO guideline for lead in drinking water is 0.01 ppm (parts per million) (WHO, 2011). The results of this research show that all the water samples did not conform to this guideline. Water from springs in Banda parish III was particularly high in its lead concentration. This could be due to poor waste disposal habits where people damp solid wastes in gutters and open spaces. These wastes are readily washed off when it rains dissolving harmful contaminants like lead into the soil and subsequently into groundwater systems. The occurrence of floods also exposes this area to lead contamination through surface runoff which carries industrial wastes from neighboring areas collecting it all in the nearby swamps after heavy rains. Lead is a cumulative poison and continued exposure to this element can result in several health hazards. Possible consequences of lead exposure are lead poisoning, anemia, nephropathy, cancer, and central nervous system symptoms (Jarvie H. P *et al.*, 1998). Its presence in water from springs in Banda at levels above tolerable limits should therefore because for concern because groundwater is the source of drinking water in areas for more than 90% of the inhabitants.

Copper

Levels of copper in the spring water ranged from 1.68 to 2.66 ppm with water from spring 6 having the highest concentration while that from spring 1 had the lowest. The permissible limit for

Table 3: Heavy Metal Contents of the Spring Water samples

Spring name	Lead (ppm)	Copper (ppm)	Cadmium (ppm)	Arsenic (ppm)
Spring 1(B1)	0.19±0.01[a]	1.68±0.00[a]	0.04±0.00[a]	0.005±0.01[a]
Spring 2(BI)	0.18±0.03[b]	1.83±0.01[b]	0.04±0.01[a]	0.006±0.00[a]
Spring 3(B1I)	0.19±0.01[a]	2.22±0.00[c]	0.06±0.02[b]	0.008±0.01[b]
Spring 4(B1I)	0.17±0.02[b]	2.58±0.02[d]	0.08±0.03[c]	0.006±0.01[a]
Spring 5(B1II)	0.24±0.02[c]	2.50±0.01[d]	0.02±0.03[d]	0.01±0.01[c]
Spring 6(B1II)	0.22±0.01[c]	2.66±0.01[e]	0.03±0.01[d]	0.01±0.02[c]

Values in the same column with the same superscript are not significantly different ($p<0.05$)

copper in drinking water is 2 ppm (WHO, 2003). The findings of this study indicate that only the water from springs in Banda parish I were within permissible limits set by this guideline. Water from springs in the other two parishes had copper concentrations above 2 ppm. Intake of copper levels less than 40 ppm poses no health risks therefore though the copper concentrations in spring water from parishes II and III are above the WHO guideline, they pose no toxicity threat to consumers of this water (Victor *et al.*, 2018)

Cadmium

Cadmium concentration in the spring water ranged from 0.02 to 0.08 ppm with water from spring 4 presenting the highest value while that from spring 5 had the lowest.

The highest desirable limit for cadmium in drinking water is 0.003 ppm and there is no relaxation for the maximum permissible limit (WHO, 2003). Cadmium is an extremely toxic metal and due to its low permissible limit, over-exposure may occur even in situations where trace quantities of cadmium are found. Levels of cadmium in water from all the springs exceeded the maximum tolerable limit and hence not safe as regards its cadmium concentration. Cadmium, like other heavy metals bio, accumulates in the body over a long period. When cadmium enters the body, it accumulates in the kidneys and can cause problems such as kidney dysfunction. Brittle bones, lung cancer, and acute pneumonia are other health effects that arise from cadmium exposure. The majority of Banda's low earners utilize springs as their source of water thus exposing a great percentage of the population to the above-mentioned risks (Liao S. *et al.*, 2008)

Arsenic

The arsenic content of the spring water ranged between 0.005 to 0.01 ppm. Water from the two springs had the highest arsenic concentration while springs 1, 5, and 6 all had the least value.

Arsenic in drinking water is a significant cause of adverse health effects such as cancer thus it is considered to be a high-priority substance for screening in some drinking water sources including groundwater sources. According to the World Health Organization, arsenic is one of the ten chemicals of major public health concern and it is especially toxic in its inorganic form. The acceptable level as defined by WHO for maximum concentrations of arsenic in safe drinking water is 0.01 ppm. This study shows that water from all the springs was within permissible limits as regards their arsenic concentration.

Coliform contamination in Spring Water from Banda

The bacterial quality of spring water drawn from 6 sites indicated that all the water samples analyzed had strains of fecal bacterial counts. Spring 6 in Banda had the highest coliform count (2,700 CFU) per 100mL of water. Generally, there was no significant difference ($p<0.05$) in the fecal coliform counts in all the water samples except for those in water from springs 4 and 6 which differed from the rest but showed no significant difference amongst themselves ($p<0.05$).

Microbiological analysis of two water samples from each of the six springs confirmed the presence of fecal coliforms. Similar to the standard set by the Environmental Protection Agency (EPA),

Table 4: Coliform Counts in the Spring Water Samples

Spring Name	Spring 1 (BI)	Spring 2 (BI)	Spring 3 (BII)	Spring 4 (BII)	Spring 5 (BIII)	Spring 6 (BIII)
Fecal Coliforms (cfu/100 mL)	1,350±70.71^{a}	1,200±41.42^{a}	1,500±56.23^{a}	2,200±82.84^{b}	1,150±12.13^{a}	2,700±74.35^{b}

Values in the same column with the same superscript are not significantly different (p<0.05)

the World Health Organization's recommended guideline for the bacteriological quality of drinking water is zero fecal coliforms per 100 mL of water. Results of this study show that water from all the assessed springs in Banda had very high fecal coliform counts.

The presence of fecal contamination is an indicator that disease-causing organisms (bacteria, viruses, parasites) could be present in a certain water supply which poses potential hazards to individuals exposed to this water. This contamination can be attributed to poor sanitation since about 80% of the population in Banda uses pit latrines and only 4% use septic tanks. As a result, much of the sewage is discharged by infiltrating water into the subsurface hence impacting groundwater quality. In many low-lying areas, pit latrines are elevated and their content is sometimes emptied into nearby tertiary channels during flooding events (Matagi, 2002). It's also common for pit latrines to be filled to a level of 5 to 10 metres deep in the occurrence of floods. As a result, all this wastewater is discharged in its untreated form and it infiltrates into groundwater giving rise to water pollution. Owing to these findings, residents of Banda are at serious risk of waterborne diseases.

5. Conclusion:

The notion that spring water is clean and safe may be wrong based on the findings of this study. The water samples from the assessed springs indicated high concentrations of lead, cadmium, and fecal coliforms as compared to the World Health Organization's recommendations for drinking water quality concerning human health. This puts vulnerable communities at risk of getting waterborne diseases. The presence of fecal coliforms in all the water samples is a good indicator that pit latrines are the key determinant of groundwater contamination in Banda. This further explains the high outbreaks of diarrhea and typhoid in this area.

6. Recommendations:

We suggest an urgent massive sensitization about water quality be conducted in these places

More research should be conducted as confirmatory tests to these findings.

7. Sources of funding:

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Author biography

Twalibu J Nzanzu Holds B.ESTM (Hons), Msc. EVS, MPH and PhD. Lecturer Kyambogo University, QA Team University

Joshua Barasa Holds BSc. Industrial Chemistry, MBA-HR

Nanyonga Sarah Kiwanuka She holds Bsc.Educ, Msc, PhD. She is a Senior Lecturer Chemistry Department Kyambogo University

JeanBosco Binenwa Holds a PhD in Leadership and Management, speciality is governance. He is the Director Graduate School and Research Directorate Kampala University Mutundwe Campus.