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Microbiological contamination of drinking water sources at tourist accommodations in South Luangwa National Park, Zambia

Celina Albanus[1 A-G], Travis W. Heggie[2 B-G], Simone Kattner[1 A,B,D-G], Thomas Küpper[1 A,B,D-G]

[1]Institute for Occupational and Social Medicine, RWTH Aachen Technical University, Aachen, Germany
[2]School of Human Movement, Sport and Leisure Studies, Bowling Green State University, Bowling Green, Ohio, USA

Original article

Abstract

Background: Water quality for tourists visiting South Luangwa National Park and other less developed regions is of the utmost importance in order to avoid gastrointestinal infections; one of the most common diseases among tourists. It is also important to the sustainability of the local tourism economy.

Methods: Water quality samples assessing microbiological contamination were taken from the borehole and point of use in 14 tourist lodges and camps. Turbidity was assessed optically with a DelAgua turbidity tube. For microbiological analysis, samples were incubated in the DelAgua Dual Incubator at 37°C and 44°C. Thermotolerant *Escherichia coli* (*E. coli*) was used as the indicator bacterium for fecal pollution. Water samples were classified based of risk levels for pollution determined by the World Health Organization (WHO).

Results: Fifty percent of borehole samples showed no contamination. Two were found to be at high risk and the others ranged between low and intermediate risk. At the point of use, 80% of the samples were clean and compliant with WHO guidelines. Water contamination generally improved from the borehole to point of use. Turbidity at borehole samples were clear in 75% of possible samples. At the point of use, turbidity was clear in 81% of samples.

Conclusion: This study establishes the first baseline water quality data for tourist facilities at South Luangwa National Park in Zambia. While water quality at most sites is clean for human use, a regular monitoring system accompanied by maintenance is recommended.

Keywords

- water quality
- Zambia
- tourist accommodations
- South Luangwa National Park

Contribution

A – the preparation of the research project
B – the assembly of data for the research undertaken
C – the conducting of statistical analysis
D – interpretation of results
E – manuscript preparation
F – literature review

Corresponding author

Travis W. Heggie, PhD, FFTM RCPS (Glasg)
e-mail: theggie@bgsu.edu
School of Human Movement,
Sport & Leisure Studies
Bowling Green
Ohio 43403, USA

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Introduction

Zambia is a land-locked country in south-central Africa. Made popular by Victoria Falls, the Zambezi River, and abundant wildlife, Zambia is becoming a popular tourist destination.[1] Within Zambia, South Luangwa National Park (SLNP) is the most important tourist attraction in the country.[2] Formally established in 1971 but receiving tourists from the 1950s, SLNP is Zambia's second largest national park encompassing 9050 km^2 of woodland savannah.[1,3,4] SLNP contains 44 lodges and camps operated by 19 different companies.[1] The approximate total capacity is 670 beds situated mostly along the Luangwa River on the eastern and southeastern border of the park.[1] Most tourists visit the park to view large game animals such as lions, elephants, hippos, and leopards.[1] Game hunting is also permissible outside of the park.[5]

Zambia is traditionally known as a mining country with metal pollution reported in aquatic environments around and downstream of mining areas.[6,7] Around SLNP, metal concentrations are low.[6] Medical conditions such as Malaria, Human African trypanosomiasis (HAT – Sleeping sickness), and Anthrax are known challenges facing travelers in Zambia and the SLNP region. However, recently concerns about the quality of drinking water available in SLNP tourist accommodations associated has been expressed. While more than 33% of the population in Zambia and over 25% of all schools are known to not have access to clean water, no baseline data exists on water quality in tourist accommodations. If SLNP is going to continue attracting more tourists and tourist expenditures, ensuring access to clean drinking water is of the utmost importance. Thus, the purpose of this study is to provide the first available data examining the levels of microbiological pollution in SLNP tourist accommodations.[4]

Methods

In May 2020, access was granted to 20 tourist accommodations within 14 lodges, high end camps, and staff quarters. Each were situated at various sites along the Luangwa River in the Chiefdom of Kakumbi. Water samples were collected from the nearest possible point of the water borehole for each of the 14 facilities. A second water sample was taken at its point of use such as at a kitchen sink or water tap inside the guest facilities. This was done to identify any point of contamination from the borehole into the lodge facility. Additionally, if water filters were in use, the second sample could help identify and evaluate even more exact contamination points.

On-site sample testing utilized a Waterproof Tester from Hanna Instruments (Woonsocket, USA) to measure water temperature and pH. The World Health Organization (WHO) establishes that the turbidity of drinking water should be 5 or less Nephelometric Turbidity Units (NTU). Water turbidity was assessed with a turbidity tube included as part of a DelAgua Dual Incubator kit (Malborough, UK). The DelAgua Dual Incubator kit was used to conduct bacteriological water analysis. To ensure the use of sterile equipment while collecting water samples, disposable sterile material (membranes, culture medium) were used and all components of the filter apparatus and Petri dishes were sterilized using burning methanol and ethanol according to the kits user manual.

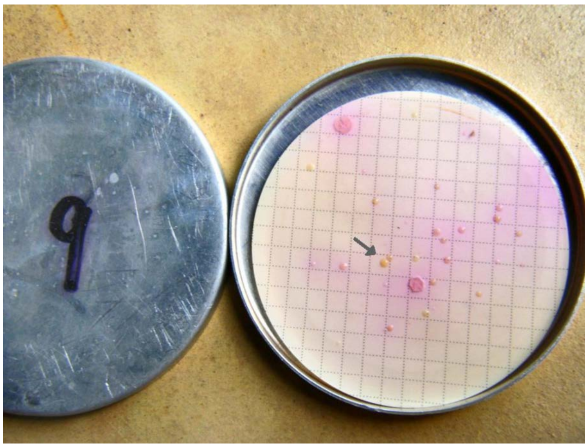

Figure 1. Water sample presenting thermotolerant coliform bacteria (arrow pointing at yellow colony) growing after incubation at 44°C. Photograph: C. Albanus

Figure 2. Water sample presenting coliform bacteria growing after incubation at 37°C. Photograph: C. Albanus

To enable bacteriological analysis, 300 ml of water were collected from the borehole water source in sterile polypropylene bottles. The samples were filtered manually through a membrane placed in the filter apparatus with sterilized tweezers. Following filtration of each sample, the membranes were placed into Petri dishes prepared with a culture medium (Membrrane Lauryl Sulphate Broth). Each sample was then incubated at 37°C and 44°C in the Dual Incubator for 16 to 18 hours. The number of heat-resistant Escherichia coli on the membranes incubated at 44°C and the coliform bacteria which had grown on the membrane incubated at 37°C were counted (Figures 1–2).

For each study location (Figure 3), the count of thermotolerant *E. coli* per water sample were classified into the following World Health Organization (WHO) Risk Categories for fecal pollution:

- Category A: 0 CFU per 100 ml – Compliant with WHO guidelines;
- Category B: 1 to 10 CFU per 100 ml – Low Risk;
- Category C: 10 to 100 CFU per 100 ml – Intermediate Risk;
- Category D: 100 to 1000 CFU per 100 ml – High Risk;
- Category E: > 1000 CFU per 100 ml – Extremely High Risk.

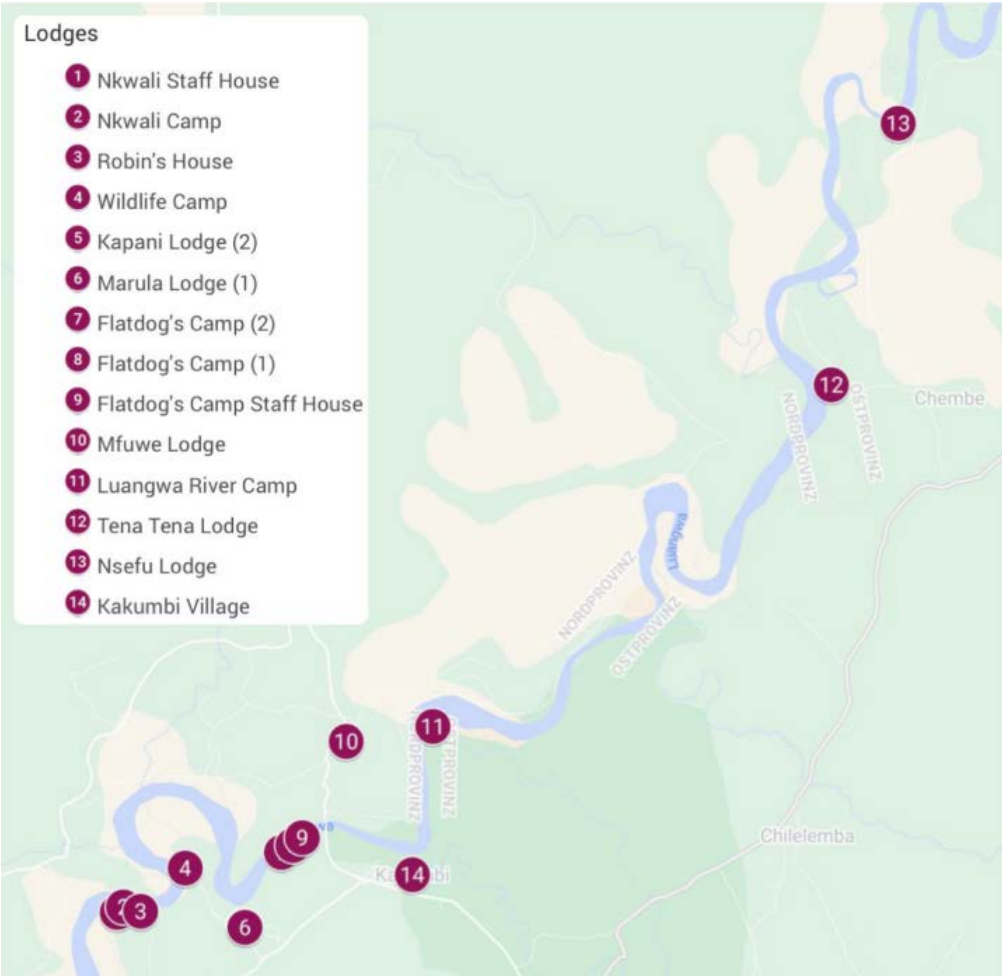

Figure 3: Study area with tourist accommodations

Table 1. Microbiological risk category and turbidity results at tourist lodges in South Luangwa National Park (SLNP)

Map #	Site Name	Risk category	Risk category	Use of filter	Turbidity	Turbidity
			Point of use		Borehole	Point of use
1	Nkwali Staff House	C	A	Yes	N/A	7
2	Nkwali Camp	D	B	Yes	N/A	15
3	Robin's House	B	B	No	50	5
4	Wildlife Camp	A	A	No	< 5	< 5
5	Kapani Lodge	B	A	Yes	< 5	< 5
6	Marula Lodge	A	A	No	< 5	< 5
7	Flatdogs Camp 1	A	B	No	< 5	N/A
8	Flatdogs Camp 2	A	A	No	< 5	N/A
9	Flatdogs Staff House	D	A	No	30	10
10	Mfuwe Lodge	A	A	No	< 5	N/A
11	Luangwa River Camp	A	A	No	< 5	< 5
12	Tena Tena Lodge	A	A	Yes	< 5	< 5
13	Nsefu Lodge	B	A	Yes	40	< 5
14	Kakumbi Village	C	A	No	< 5	**< 5**

Risk Category A = Compliant with WHO guidelines for fecal matter. Category B = Low risk, Category C = Intermediate risk, Category D = High risk, Category E = Extremely high risk. Turbidity was measured in Nephelometric Turbidity Units (NTU). N/A represents sites where turbidity levels were unable to me measured.

Results

The results of the water samples, their associated risk category, and their turbidity results are reported in Table 1. From the samples taken directly from boreholes closest to the point source of water, seven (50%) were found to have no trace of *E. coli* and compliant with WHO guidelines (Risk Category A). Two were found to be at high-risk (Risk Category D), two were found to have an intermediate risk (Risk Category C), and three were found to have a low risk (Risk Category B). At the point of use, 11 (79%) of the facilities were designated in Risk Category A and compliant with WHO guidelines. The remaining three facilities were found to have a low-risk for fecal matter (Risk Category B).

Only five of the lodge facilities had filters in place between the borehole and the point of use. Based on their borehole risk category, six of the facilities risk categories improved when sampled at the point of use, seven remained in the same risk category, and one facility moved into a higher risk category. Nkwali Camp and Flatdogs Staff House were both high-risk category D when sampled at their borehole. When sampled at their point of use, Nkwali Camp improved to Category B (low risk) and the Flatdogs Staff House improved to Category A (safe). Nkwali Camp has a filter in use between their borehole and point of use and the Flatdogs Staff House does not. The Nkwali Staff House improved from an intermediate risk to a safe reading, Kapani Lodge improved from a low risk to a safe reading, and Kakumbi Village improved from an intermediate risk to a safe reading. Out of the six test sites where water quality improved, four were equipped with filters.

Water turbidity was able to be measured at 23 of the 28 borehole and point of use sites. Out of this total, 7 (33%) of the samples indicated locations with high levels of suspended and / or dissolved particles in the water. Robin's House had the highest borehole turbidity level at 50 NTU, Nsefu Lodge registered 40 NTU, and Flatdogs Staff House registered 30 NTU. At the point of use, Nkwali Camp registered 15 NTU, Flatdogs Staffhouse recorded 10 NTU, Nkwali Staff House recorded 7 NTU, and Robin's House recorded 5 NTU. Water turbidity comparisons between the borehole and point of use site was only possible at eight sites. At six of these sites, water turbidity remained the same at safe levels. At two sites, Robin's House and the Nsefu Lodge, the turbidity levels improved.

Discussion

This study provides the first known data on drinking water quality at tourist accommodations in the remote region of South Luangwa National Park. It is a basic requirement that water systems used in tourist facilities such as those in SLNP be clean and healthy.[14,15] Failure to meet this requirement could impact the health of tourists by way of illnesses such as traveler's diarrhea.[16] For example, in water studies the growth of coliform bacteria indicates pollution in general while E. coli levels indicate contamination by human, wildlife, and livestock feces.[17] While other coliform bacteria do not tolerate heat, *E. coli* can be identified after incubation at 44°C. Therefore, drinking guidelines listed by the WHO does not allow for any thermotolerant coliform bacteria to occur in 100 ml water samples.[16]

The WHO considers water sources such as those in SLNP to be prone to contamination.[18] Fortunately, only the Flatdogs Staff House and Nkwali Camp borehole samples were considered high risk (Category D) and both locations improved to low risk or no risk when sampled at their point of use. To put this into perspective, the Environmental Protection Agency (EPA) associates this reading with 32 illnesses per 1000 people.[18] Overall, water quality samples in this study almost all improved or stayed at no risk (clear and safe drinking water) from the borehole to their endpoint point of use. Only the Flatdogs Camp 1 was the exception to this trend. Flatdogs Camp 1 utilizes no filter and the water from the endpoint point of use indicated the presence of fecal contamination whereas the borehole provided clean and safe water. This raises the question of secondary contamination along the pipe network. However, finding the exact point of pollution is difficult to determine because the pipe network is underground and because contamination along the network may occur in areas with corroded pipes or poor pipe connections. It is therefore recommended that Flatdogs Camp 1 replace the pipeline from the borehole to the point of use. It is also recommended that Flatdogs Camp 1 utilize a filter between their borehole and point of use. Although not all locations in this study utilize a filter, the data strongly suggests an improvement in water quality at the locations with a filter between the borehole and point of use. Such filters can only improve water quality and along with the proper maintenance of boreholes, pipelines, and filters, peak water quality conditions can be achieved.

There are many factors that can factor into water quality and water quality testing in the area around SLNP. For example, water quality may be influenced by seasonal changes due to rainfall and other environmental aspects. Wastewater and latrines may be spread during rainfall or episodes resulting in increased water levels. Single water points such as boreholes or village wells often lack maintenance and may be poorly sealed. Thus, they are vulnerable to contamination and require vigilant monitoring and maintenance. A similar study conducted in the township of Petauke, Zambia raised the concern of wastewater contamination during the rainy season when comparing water quality between the rainy and dry season.[19] However, pollution due to flooded boreholes presents little risk to tourist accommodations in SLNP because the lodges in this study only operate for half a year in the dry season and are not accessible during the wet season. The samples in this study were taken during the peak dry / tourist season and represent the overall quality of water during this season.

It should be noted that the DelAgua bacteriologic analysis used in this study is based on thermotolerant and total coliform bacteria as indicator organisms. Though *E. coli* is the indicator bacteria of choice for the WHO, the absence of *E. coli* is not a guarantee for microbiological safety. For example, in this study the growth of other bacterial colonies was observed and could crowd out coliform bacteria on filter membranes if their number was considerably higher. In the turbid water samples, the dissolved solids precipitated on the filter membrane can impede the growth of indicator bacteria such as *E. coli* or interfere with the readings due to its yellow color. Thus, there is a chance of false-negative results among the turbid samples.

Conclusion

The purpose of this study was to generate the first available baseline data examining water quality in tourist lodges situated around South Luangwa National Park in Zambia. Most of the water quality samples taken in this study showed positive trends making the area safe for visiting tourists. This is important given the overall importance of clean water for visitors to the area. However, it is recommended that a regular monitoring system examining the level of any potential microbiological pollution in the boreholes, pipelines, and point of use be put in place. Any required maintenance should be carried out immediately.

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