Original Research Article

Evaluation of the quality of undeveloped spring waters consumed directly by the local population of Kasai in the Democratic Republic of Congo

ABSTRACT

Objective: Contribute to the assessment of the quality of undeveloped spring water consumed by the local population of the province of Kasai in the Democratic Republic of Congo.

Design of the study: This study consists of four parts, an introduction with literature review, a description of the study environment and sampling site, the materials and methods used and finally the presentation and discussion of the results obtained.

Location and duration of the study: This study was conducted in the province of Kasai, in the villages of Kamupafu, Kabilowa, Kayonga, Kankondo, Kankala, Lunyanya and Kumbikumbi in the town of Tshikapa. The study covered the period from September 29 to October 24, 2022.

Methodology: The water samples taken (27) were prepared in the laboratory according to standard procedures and a series of physico-chemical and microbiological characterization analyzes were carried out in the field and in the laboratory. The data collected was processed and analyzed using SigmaStat 11.0 statistical software.

Results: Among other results obtained, it appears that the average pH was between 4.6±0.15 and 6.96±0.43; the EC between 12.91±0.51 $\mu S.cm^{-1}$ at the Dido/Milonga spring and 26.87±3.00 $\mu S.cm^{-1}$ at the Tshitenga spring. The turbidity, the soluble ion (NO_3^-, F^-) and arsenic (As) contents in the water reveal that with the exception of the turbidity in the Kamitutungulu spring (10 ± 1.04 NTU), the concentration of the other elements in the water from all the springs studied complies with WHO recommendations for drinking water quality. In addition, the average values (CFU 100 mL^{-1}) of total coliforms vary between 18 (KAMANKONDE/ROBERT) and 81 (KATOKA 3) for waters of all the springs.

Conclusion: All spring waters analyzed reveal microbiological contamination by bacteria indicating faecal pollution (coliforms). It's therefore suggested that support be provided in terms of drinking water supply and hygiene by setting up village water supply structures.

***Keywords**: Evaluation, quality, water, undeveloped spring water*

1. INTRODUCTION

The world is now experiencing rapid urbanization that is leading to an increase in disadvantaged urban populations, which reinforces the exclusion of the poorest and most marginalized people, and increases inequalities in access to water, sanitation and hygiene (WASH) services (Adongo, 2022).

The international decade for drinking water and sanitation (1981-1990) decreed by the United Nations breathed new life into the sector of drinking water supply and sanitation (AEPA). Its mission was to promote access to drinking water for all. Its target group was low-income rural and urban communities. Four guiding principles have been proposed to enable equitable sharing of water (CREPA, 2003):

- protecting the environment and safeguarding health through the integrated management of water resources and both liquid and solid waste;

- institutional reforms aimed at promoting an integrated approach, a change in methods, attitudes, behaviors and the full participation of women at all levels;

- community management of services, supported by measures aimed at strengthening the capacity of local institutions to implement and sustainably manage drinking water supply and sanitation problems;

- sound financial management, thanks to better management of existing equipment and the generalization of appropriate technologies.

Also, in this perspective, SDG 6 aims to ensure universal access to drinking water and sanitation, but also to improve water quality and to contribute significantly to the reduction of pollution, and among other things to ensure adequate use of water (Génevaux, 2018). The National Water and Sanitation Action Committee at the national level is responsible for coordinating actions.

The rural world in the province of Kasai, as mentioned before, is supplied with drinking water through numerous water points, mainly groundwater, whether developed or not, and sometimes rainwater collected from the roofs of houses; most spring water are not protected in any way.

However, unlike in urban areas, water supply in rural areas is very restrictive and even very complex, since women and children are forced to travel many kilometers to fetch water. They leave early in the morning and return late with a weight of up to fifty kilos. Women therefore spend more time in search of drinking water, sacrificing other productive household activities.

1.2. Objective

The objective pursued in this study is to assess the quality of undeveloped spring water consumed directly by the local population of the province of Kasaï in the D.R. Congo in order to satisfy sustainable access to drinking water in the province of Kasaï.

2. STUDY SITES, MATERIAL AND METHOD

Kasaï has been a province of the Democratic Republic of Congo since 2015 following the break-up of the province of Kasaï Occidental. With an area of 95,631 km² and a total population of 2,978,000 inhabitants, it is located in the center of the country on the Kasai River, between 5° 21′ 00″ South and 21° 25′ 00″ East (DRC Statistical Yearbook 2017; MICS Palu 2017-2018) (Fig. 1).

The province of Kasai is one of the provinces of the country affected by water shortage. This province is experiencing a shortage that restricts access to drinking water to the local population, which often obtains water of poor quality and in insufficient quantity compared to needs, with all the consequences for human health.

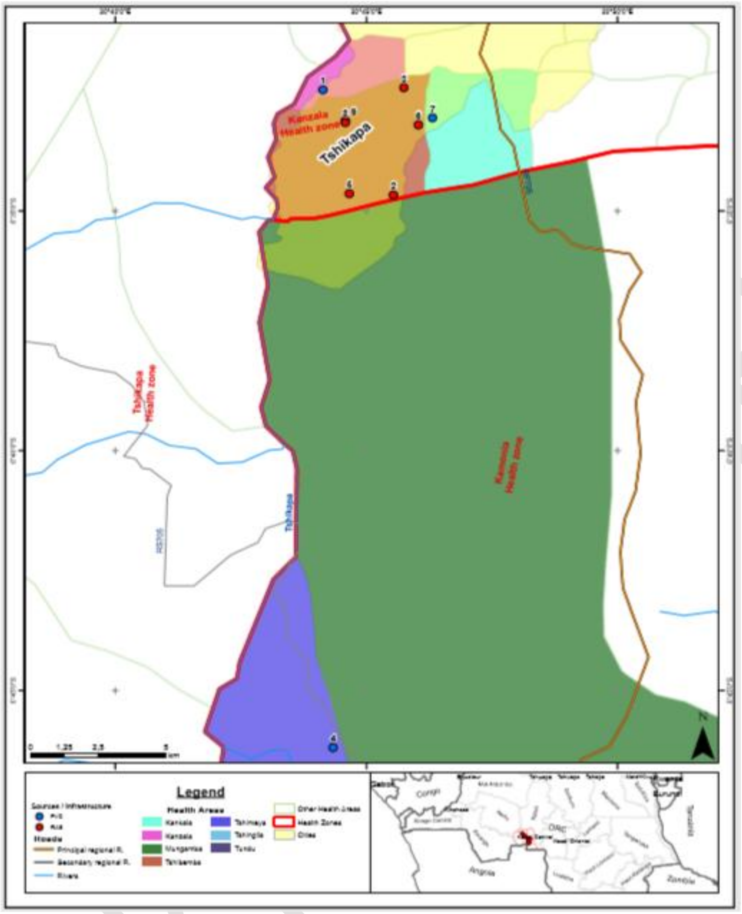

Fig. 1. *Map of Kasaï province with overview of sampling sites in Tshikapa*

2.1 Methodology

2.1.1 Observation

Observations made at the sampling sites reveal questionable macroscopic characteristics (Fig. 2). Indeed, the indices on the coloring and the odors of the waters reinforced these observations and made it possible to formulate the first hypotheses on a possible contamination and the need to proceed by the characterization analyzes to evaluate the quality of these spring waters consumed by the population.

__Fig. 2.__ Some sampling points in the 9 sites (photos taken Nyembo in September 2022).

2.1.2. Water sampling procedure

According to the strategy implemented by Kapembo et al. (2019), 27 spring water samples were taken manually in triplicate at 9 sites.

Water is collected by directly dipping a polypropylene plastic container (500 ml) into it. Once collected, the samples were stored in a cooler at 4°C and transported to the laboratory for analysis within 24 hours according to Mukeba et al. (2021). The samples were labeled according to the name of the village where they were taken. The geographical coordinates of the sampling sites and the names of the villages and springs are reported in Table 1 below.

Table 1. GPS coordinates of spring water

Village	Name of Water spring	Geographical coordinates		Distance
		Latitude	Longitude	
KAKONDO	KATOKA 3	S6°46’11,557’’	E20°44’20,569’’	1 000 m
KANKALA 2	BAFANA	S6°34’38,51’’	E20°44’39,624’’	830 m
FERME DIDO	KAVUDI 2	S6°32’28,885’’	E20°44’8,257’’	1020 m
FERME DIDO	DIDO/MILONGA	S6°33’7,499’’	E20°44’34,836’’	600 m

FERME DIDO	FERME DIDO	S6°33’9,828’’	E20°44’34,738’’	630 m
LUNYANYA	TSHITENGA	S6°33’12,449’’	E20°46’2,1’’	680 m
KIBILOWA 1	KAMANKONDE/ROBERT	S6°34’40,354’’	E20°45’32,392’’	900 m
KUMBIKUMBI	KATSHIBANGU	S6°33’3,812’’	E20°46’19,3’’	800m
KAYINGA	KAMITUTUNGULU	S6°32’26,167’’	E20°45’44,805’’	800 m

2.1.3. Physico-chemical characterization of water

Electrical Conductivity (EC) and total dissolved solids, were measured in situ using a Multi 350i (WTW, German brand). The concentration of dissolved ions (NO_3^-), arsenic and fluoride was measured using ion chromatography (Dionex ICS3000, Canada) according to the method described by Mavakala et al. (2016); Kilunga (2016). In addition, the certified water material (CRM, Ontario-99, Water Research Institute, Canada) was used to verify the instrumental precision following the technique described by Mukeba et al. (2021). Thus, the results obtained from the CRM were within the acceptance range indicated on the CRM certificate.

2.1.4. Microbiological characterization of water

Faecal indicator bacteria [including Faecal Coliforms (FC) and Total Coliforms (TC)] were quantified in water samples according to international standard methods for the determination of water quality using the membrane filtration method (APHA, 2005; Kapembo et al., (2019). For each sample, triplicates of 100 mL of water were passed through a 0.45 mm filter (Sartorius stedim, biotech, German brand), then placed on different selective culture media (Biolife, Italiana), using the following incubation conditions :

- For the analysis of ENT bacteria: each water sample was inoculated in Slanetz Bartley Agar (SBA) medium and incubated at 44°C for 48 h, then transferred to Bile Aesculin Agar (BAA) medium at 44°C for 4 h, and to Endo Agar medium, incubated at 35°C for 24 h for CT.

The results are expressed in colony forming units (CFU) per 100 mL of water sample (CFU 100 mL^{-1}). The reproducibility of all experimental procedures was tested using triplicates. Field and laboratory checks were carried out as described in previous studies (Kilunga et al., 2016; Nienie et al., 2017).

2.1.3. Analyses statistiques

All water sample analyzes were performed in three replicates per dilution to perform FIB quantification to establish the standard deviation of colony count (Kayembe et al., 2018). Statistical analysis of data was conducted using SigmaStat 11.0 (Systat Software, Inc.). Data were subjected to a Spearman rank correlation test to investigate possible relationships using RStudio statistical software, version 1.3.1093, © 2009-2020 RStudio, PBC.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Physico-chemical characteristics of spring water

The results of water physico-chemical parameters including temperature (T), pH, electrical conductivity (EC) and dissolved solids (TDS) of the spring waters are reported in Table 2. The values of T, EC, TDS and turbidity observed at all sampling sites are within the values recommended by the World Health Organization guidelines for drinking water quality (WHO, 2017).

Table 2. *Physico-chemical parameters (ET temperature, pH, Electrical Conductivity (EC) and Dissolved Solids (TDS)) of water samples from springs at 9 sites.*

Name of Water spring	**T°C**	**pH**	**EC (µS/cm)**	**TDS (mg/l)**
Kavudi 2	25.4±0.22	6.25±0.12	18.30±0.56	9.01 ± 0.90
Kamankonde/Robert	25.1±1.15	4.6±0.15	17±1.12	8.36 ± 0.53
Kamitutungulu	26±0.3	5.63±0.36	32.5±2.14	16.3 ± 1.50
Mwabeya 1	25.6±1.2	4.68±0.25	20±1.50	9.58±0.53
Bafana	26.4±0.3	5.37±0.11	24.32±1.84	12.08±0.23
Tshitenga	26.5±0.29	5.7±0.55	26.87±3.00	12.89±0.40
Katshibangu	26.1±0.4	6.5±0.30	17.8±1.14	8.69±0.80
Ferme Dido	25.3±0.46	6.96±0.43	26.84±0.96	13.07±0.12
Dido/Milonga	25.4±0.6	6.20±0.30	12.91±0.51	6.45±0.42
WHO standards*	**25**	**6.5-9**	**100-1500**	**<500**

* Limit recommended by the World Health Organization guidelines for the quality of drinking water (WHO, 2017).

The water temperature was higher in the waters of four springs, namely: Katshibangu, Kamitutungulu, Bafana and Tshitenga, with maximum values respectively around 26.1±0.4; 26±0.3 ; 26.4±0.3 and 26.5±0.29^0 C. The pH was between 4.6±0.15 and 6.96±0.43. For the CE, the maximum value of 26.87±3.00 µS.cm^{-1} was observed at the Tshitenga spring and the minimum value of 12.91±0.51 µS.cm-1 was observed at the Dido/Milonga spring. With regard to the TDS, the values obtained were between 6.45 ± 0.42 and 16.3 ± 1.50 mg.l^{-1}.

Statistical analysis of variance revealed a significant difference ($P \leq 0.05$) between all parameters analyzed in the nine springs. These values are similar to those of other studies conducted in environments with almost the same characteristics in tropical areas (Nienie et al., 2017; Mukeba et al., 2021). On the other hand, the values obtained by the present study are lower than the values observed by Kapembo et al. (2016) in the waters of springs and wells in the municipalities of Bumbu (Kinshasa). These waters are weakly acidic and little ionized.

Table 3. *Physico-chemical parameters (Turbidity, Nitrates (NO3-), Fluorides and Arsenic of water samples from springs at 9 sites.*

Name of Water spring	**Turbidity (NTU)**	**Nitrates (mg/l)**	**Fluorides (mg/l)**	**Arsenic (µg/l)**

Kavudi 2	0.0	16.28±0.10	0.36±0.01	-
Kamankonde/Robert	0.0	2.34±0.12	0.38±0.11	0.02
Kamitutungulu	10±1.04	2.26±0.19	0.36±0.02	0.003
Mwabeya 1	0.0	1.44±0.23	0.34±0.05	-
Bafana	0.0	7.20±0.05	0.30±0.03	-
Tshitenga	0.0	10.60±0.07	0.0	-
Katshibangu	1.0±0.57	1.35±0.39	0.40±0.04	0.02
Ferme Dido	0.0±	5.41±0.06	0.30±0.02	0.07
Dido/Milonga	1.0±1.12	10.38±0.29	0.37±0.01	-
WHO standards*	**<5 NTU**	**< 50 mg/l**	**< 1.5 mg/l**	**10 µg/L <**

* Limit recommended by the World Health Organization guidelines for the quality of drinking water (WHO, 2017).

The concentration of turbidity, soluble ions (NO3-, F-) and arsenic (As) in the water samples are reported in Table 3. With the exception of turbidity in the Kamitutungulu spring (10 ± 1.04 NTU), the concentration of the other elements in the water samples from all the springs studied is in accordance with WHO guidelines for drinking water quality (WHO, 2017). Moreover, all the concentrations obtained varied significantly according to the sampling sites ($P \leq 0.05$).

Several recent studies have addressed the issue of nitrate levels in groundwater and its potential risks to human health (Mukeba et al., 2021; Adimalla and Qiana, 2021). Indeed, the low concentrations of NO_3^- observed in the spring waters studied are much lower than those found by Mukeba et al. (2021) in the urban environment of Bumbu and Kimbanseke communes in the city of Kinshasa where the NO_3^- ion content exceeded WHO recommendations. This difference could be explained by several aspects, including the absence of agricultural activities in the surroundings likely to contaminate seepage water rich in chemical fertilizers, the low permeability of the unsaturated zone, the depth of the aquifer, etc. (Abdelaziz et al., 2007; Kapembo et al., 2016).

3.1.2. Microbiological quality of spring water

The microbiological quality of the water samples taken from the springs is presented in Table 4. For these undeveloped springs, the mean FIB values (faecal coliforms and total coliforms) were between (2 – 5) x 10^3 and (18 – 8111) x 10^3 CFU 100 mL^{-1}, for faecal coliforms and total coliforms respectively. Levels of fecal coliforms and total coliforms in water samples varied significantly between sampling sites and seasonal variations ($P < 0.05$). Bacteriological water pollution was significantly higher with respect to total coliforms. Indeed, in the waters of all springs, the average values (CFU 100 mL^{-1}) of total coliforms vary between 18 (KAMANKONDE/ROBERT) and 81 (KATOKA 3).

As for pollution by faecal coliforms, some springs have been concerned by the presence of germs. But surprisingly, no faecal coliform contamination was observed in the water samples taken from 5 of the 9 spring (KAMANKONDE/ROBERT, BAFANA, TSHITENGA, FERME DIDO and DIDO/MILONGA).

Table 4. *Microbiological analyzes of spring waters*

Name of Water spring	**FECAL COLIFORMS (CFU ± SD x 10^3 100 mL^{-1})**	**TOTAL COLIFORMS (CFU ± SD x 10^3 100 mL^{-1})**

KAVUDI 2	5 ± 1.51	40 ± 0.91
KAMANKONDE/ROBERT	0	18 ± 3.37
KAMITUTUNGULU	3 ± 0.25	19 ± 1.02
KATOKA 3	2 ± 0.23	81 ± 1.30
BAFANA	0	15 ± 2.51
TSHITENGA	0	80 ± 11.8
KATSHIBANGU	3 ± 0.79	40 ± 1.36
FERME DIDO	0	65 ± 1.88
DIDO/MILONGA	0	69 ± 1.13
WHO standards*	0	0

* Limit recommended by the World Health Organization guidelines for the quality of drinking water (WHO, 2017).

These results suggest the presence of faecal contamination (total coliforms) in at least all springs, indicating that the water from these springs cannot be used for domestic purposes according to the WHO regulations for water for domestic use, which recommends 0 CFU 100 mL^{-1} (WHO, 2019). These springs are undeveloped and unmanaged (considered public property), close to cattle ranches, etc. This constitutes a great challenge for users for public health since these waters are often consumed raw. Our observations corroborate those of Nienie et al., (2017) in their study carried out in a similar environment (Kikwit, DRC). Indeed, these authors stipulate that during the rainy season, for example, rainfall in tropical areas is of great intensity and carries contaminated soil from the watersheds which, in turn, contaminates streams, rivers and springs with faecal matter, especially during the rainy season.

The results of this study demonstrated that the microbiological analysis of water samples from 100% of the unmanaged/undeveloped springs (with the exception of 5 springs for faecal coliforms) is highly contaminated with faeces. Therefore, water from these springs is likely to contain pathogenic organisms that cause water-borne diseases such as gastrointestinal diseases, typhoid, cholera and other diarrheal diseases (WHO, 2011; US EPA, 2000). The deterioration of the microbiological quality of water from these springs can be explained by several causes, including open defecation and the short distance between toilets and spring water, percolation of contaminated surface soils during rainfall events, infiltration of toilets located near springs, and direct contamination by users who are not aware of the management of drinking spring waters.

3.1.3. Corrélation statistique

The data obtained was subjected to a Spearman order correlation analysis which made it possible to identify the possible relationships between the parameters analyzed. The results of this analysis are shown in Table 5 below.

In general, no significant correlation was observed between the physicochemical parameters and the bacteriological parameters (faecal coliforms and total coliforms) of these spring waters.

Table 5. *Spearman order correlation of selected parameters in spring water*

	T °C	*pH*	*CE*	*TDS*	*Turbidité*	*Nitrates*	*Fluorures*	*Arsenic*	*Coliformes fécaux*	*Coliformes totaux*
T °C	1									
pH	-0,26816633	1								
CE	0,30422013	-0,03085112	1							
TDS	0,26560701	-0,35863155	0,0275283	1						
Turbidité	-0,12777503	-0,10487778	-0,10125996	-0,10413278	1					
Nitrates	-0,16490797	0,19491822	0,20415065	-0,04938775	0,28371319	1				
Fluorures	-0,23274035	-0,05929906	0,03851781	0,00881812	0,04173698	-0,08790066	1			
Arsenic	-0,09630099	0,18711151	-0,03179052	0,0512063	-0,14143328	-0,03668091	0,33984747	1		
Coliformes fécaux	0,17392841	0,27867873	-0,05284439	-0,08115997	0,15021933	0,03528893	0,03241199	-0,10865438	1	
Coliformes totaux	0,0166182	0,47791938	0,0910007	-0,12243778	-0,32543253	0,06977259	-0,44331538	0,05600656	0,07571938	1

These results suggest that the physicochemical and bacteriological parameters can be considered as coming from different origins. However, a significant positive correlation was observed between Total Coliform and pH (R= 0.47791938, P < 0.001) and between Total Coliform and pH again (R= 0.27867873, P < 0.001). These results indicate that faecal coliform and total coliform could not come from common origin and be transported in the sources by common transporters. Observations made by this study are different from those made in some previous studies (Poté et al., 2009; Kilunga et al., 2016) which showed that the two forms of pollution often correlate.

4. CONCLUSION

This article has made it possible to understand and know the place of water, sanitation and hygiene in rural and peri-urban areas in the areas of the province of Kasaï in the DR. Congo and the role of women also partnership through its activities and their impact on the environment. Therefore the following conclusions can be drawn :

- Access to Water, Hygiene and Sanitation remains very limited in the DRC, in rural areas.
- In Kasai, the Water, Hygiene and Sanitation component is full of organizational and promotional weaknesses in health, school, public structures, etc. None of the water samples analyzed were found to be drinkable.
- Issues related to improving the conditions of access to drinking water and sanitation in rural areas must be resolved in a sustainable perspective.
- The sociological, cultural, environmental, political and economic factors that could hinder the success of the said projects should be analyzed beforehand and carefully studied by involving upstream and downstream all the development actors, namely the rural populations who are the real concerned and the political decision-makers or promoters of the projects.
- -Set up a structured consultation framework.

Scientific support is therefore suggested for the various actions carried out by numerous organizations or research centers in terms of drinking water supply and hygiene through the establishment of village water supply structures, communication for a change in behavior and socio-economic actions in favor of disadvantaged grassroots communities in a sustainable perspective.

It is imperative to promote research on drinking water and sanitation across the country in order to reduce the likelihood of waterborne diseases.

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