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Quality of water resources of Mount Lubwe and its access in a context of landscape anthropization in the Butembo region, East of DR Congo

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This study highlights the competitive effects of the exploitation of the resources of Mount Lubwe on the quality of the water resources. The objective is twofold and consisted in: (i) evaluating the physico-chemical and microbiological water quality in the current context of anthropization of Mount Lubwe vis-à-vis the standards of the World Health Organization (WHO) and (ii) determine the conditions of access to this resource in the beneficiary communities of the region. The systemic analysis approach shows that the anthropogenic pressure on the natural forest ecosystems has induced the degradation of water quality as well as its availability in the beneficiary areas of Butembo region. Most of the surveyed water sources provide water that exposes consumers to many health risks. The high rate of germs (45,000 UFT/ml) and nitrites content (0.1245 ml/l) is an indicator not only of the poor quality of its water resources but also of the impacts of anthropization of the landscape. Moreover, access to water shows a marginalization based on social categories with only people with stable and regular incomes who can afford quality drinking water.

Key words: Water resources, Mount Lubwe, access to drinking water, Butembo region.

INTRODUCTION

The degradation of forest ecosystems and its influence on the quality of water resources is extensively debated around the world. This is an issue that currently captures the attention of many researchers; because of the role that forests play in human survival and well-being (Bakouma, 2010). The forest provides humans with

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various ecosystem services including the permanent supply of quality drinking water. As the world faces several environmental crises, including that of water, the question of the management of forest ecosystems that provide this service to humanity is becoming increasingly crucial (Ndona Nzey, 2003). In several regions of the planet, quality water in required quantity is becoming more and more scarce due to the overexploitation of the resource and the inadequate land use (Calder et al., 2007). Stolton and Dudley (2007) point out that efficient and sustainable forest management contributes enormously to the supply of cheap and potable water.

In the Democratic Republic of Congo, forests and water resources are interconnected in such a way that disruption of one has negative effects on the other (Chishugi et al., 2021). de Wasseige et al. (2008) point out that the supply of water in quantity and quality in the Congo Basin is dependent on the forest. However, due to the lack of coherent land use planning at the national level coupled with various socio-political crises, the forest and water balance is gradually deteriorating. Annually conversion of forest cover into agricultural land without prior planning or even in transgression of the law in force is increasingly taking place (*de* Wasseige et al., 2008; Chishugi et al., 2021).

For three decades now, North Kivu is experiencing recurrent episodes of theaters of armed conflict and the environmental consequences of such a situation are well obvious. This instability forces people to congest in certain areas that are still secure, living on subsistence activities, with agriculture remaining the bedrock of their economy. Land scarcity in these densely populated regions forces farmers to continuously cultivate the small portions of land in their possession with rudimentary practices which are not likely to guarantee the sustainability of production. The land scarcity and fragmentation is subsequent to population growth in this province, where a number of villages is rapidly expending with profound change in the landscape and the habitat (Bruneau and Kasay, 1981).

The city of Butembo and its surroundings are part of areas where access to drinking water is an acute issue. Mount Lubwe, a natural reserve located more than 30 km from the city, has become an essential water tower for the latter. The existence of this protected area arises tension and land rivalry between the bourgeois logic of land accumulation and the peasant logic of land conservation. However, the conflict between objectives of land use by local populations and urban beneficiaries for water services provided by this space continues to grow and disrupts natural landscapes. Knowledge concerning the influence of human activities on the water quality and quantity is still scarce but requires more attention. Indigenous knowledge about natural resource management and the perception that the local community has with regard to natural resources is key for their sustainable management. Mount Lubwe is regarded as cultural sanctuary for some and a water tower for others. This is assumed to provide enough protection to the Mount Lubwe ecosystem. However, the ground truth reveals an intensive poaching of human activities, mainly agriculture and charcoal production, on the forest ecosystem of this mountain. It is in this context that this study was carried out, not only to assess the quality of the Mount Lubwe water sources in the context of the anthropization of its natural forest ecosystems, but also to determine the accessibility of this resource in the beneficiary communities of Butembo region.

MATERIALS AND METHODS

Study site

This study was carried out in four different sites, namely the Lubwe and Ngeleza villages as well as Kimemi and Mususa municipalities of Butembo city as illustrated in figure 1. Lubwe and Ngeleza sites host Mount Lubwe; Mihake and Musienene villages. Musienene and Mihake villages are located in the Baswagha chiefdom in the territory of Lubero, North Kivu/DRC. Musienene is located at an altitude of 1880 m at 0°00'53.15'' North; 29°16'54.73''E, about 15 km South to Butembo city. Mihake is a village located not far from the Lubwe landscape about 5 km from Ngeleza (southward the mountain). It is located between geographical coordinates 0°00'31.00''South and 29°17'59.71'East and at 1920 m above sea level. The urban area of Butembo lays between the latitude 0°05' and 0°10' North and longitude 29°17' and 29°18' East, with an average altitude of 1700 m. Its landscape is part of the mountainous Kivu region in Central Africa (Vyakuno, 2006). Butembo city is subdivided into four municipalities, namely Bulengera, Vulamba, Kimemi, and Mususa. This study focused on Kimemi and Mususa municipalities due to their high dependence on drinking water supplied from Mount Lubwe (Vikanza, 2013).

Data collection

Data collection consisted of, on one hand, the use of reports, archives, papers and related studies and on the other hand, field work consisting of surveys and water sampling as well as field observations. The observations consisted of scanning through the landscape of Mount Lubwe, identifying the main springs that supply rural and urban settlements. At the end of these observations, five different springs on Mount Lubwe were selected for physico-chemical and microbiological analyses of their water. These springs are managed by the local associations (ACEKA and ACEKAVU) to supply water in Butembo city and its peripheral agglomerations of Musienene, Ngeleza, Mukohwa and Mihake.

For each spring, one water sample was collected *in situ* on Mount Lubwe for quality analyses. To limit any risk of cross-contamination, sterile jars were used for samples intended for microbiological analyzes (Alégoet and Rhône-Alpes, 2006; CCME, 2011), whereas ordinary plastic bottles were used for samples intended for the physico-chemical analyses (Bigonnesse and Roy, 2017). In this perspective, the jars were opened only at the place of sample collection, and in the laboratory to limit the risk of contamination by the air. In addition, cool boxes containing cold packs were used during the transportation of the samples from the sampling site to the laboratory. These accumulators made it possible to obtain the desired temperature of 1 to 4°C (El Youssefi, 2014) in order to slow down microbial growth by the cold and thus avoid any bias in the results (Bigonnesse and Roy, 2017).

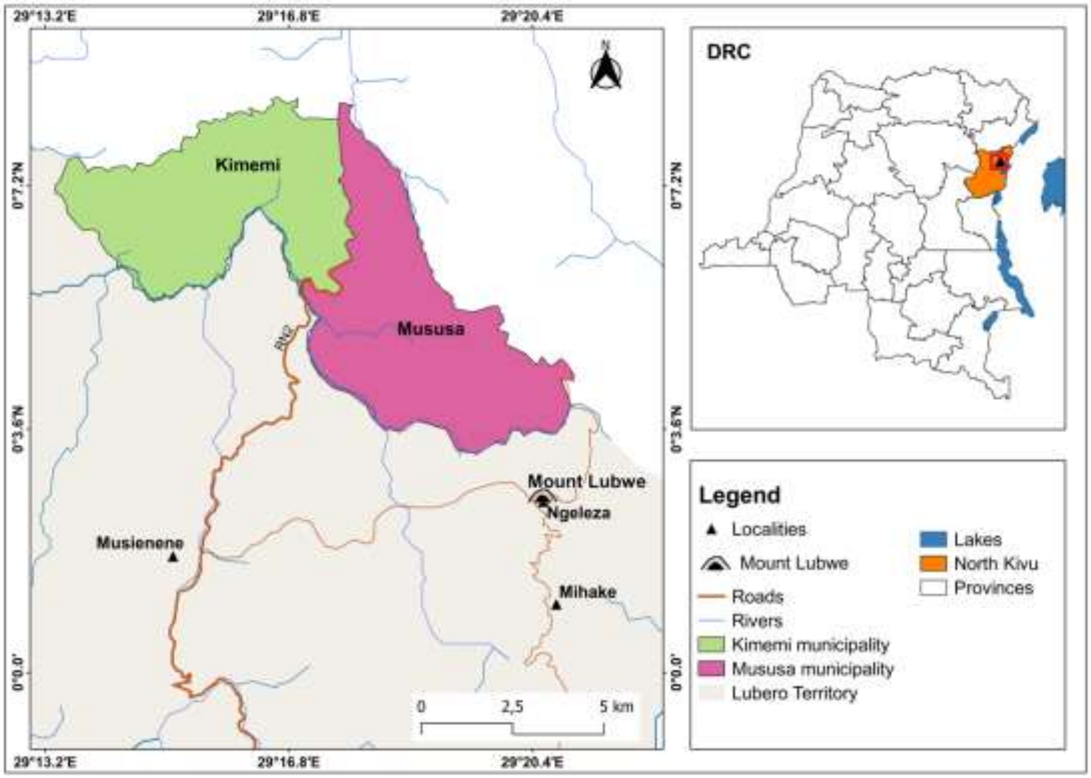

Figure 1. The location of Mount Lubwe in the Butembo/Nord-Kivu-DRC region.
Source: Authors.

Regarding survey data, they were collected in Butembo and in twosurvey data, they were collected in Butembo and in two villages: Musienene and Mihake. These surveys mainly consisted of collecting the perceptions of the various actors on access to drinking water in a systemic and global dimension. This systemic dimension was carried out at three levels: the perception of the quantity of drinking water in the agglomeration, the willingness to pay for the improvement of access to the drinking water, and the use of water treatment methods before domestic use. The sample size was determined systematically using the law of probability (random). The household was the study unit and the number of households to be surveyed was determined on the basis of the demographic weight in the agglomeration according to the following formula of Yamane (1967):

$$n = \frac{N}{1+N(e)2}$$

where n: sample size, N: the size of the population, and e: the degree of precision. In total, 611 households were surveyed. These households were randomly selected among the beneficiaries of water supplied by Mount Lubwe and their neighbours who do not source from Mount Lubwe water supply plants.

Water physico-chemical and microbiological analyses

Theses analyses involved the electrical conductivity, turbidity, pH, nitrates and nitrites, hydrometric title, calcium and magnesium ions, chlorides, the total coliforms, faecal coliforms and polluting germs. The results of these parameters were compared to the WHO standards for drinking water as illustrated in Table 1. For microbiological analyses, the most probable number method (a dilution method) was used to count the germs (Hugues, 1981). This method enables the assessment of the microbiological growth by a turbidity of the medium contained in the test tubes. Two culture media were used, namely tergitole and Tryptone Soya Bouillon. Results were interpreted in reference to the table of Marc Grady (1915) cited by Maul (1982). The total number of germs was determined according to the formula:

$$Number\ of\ germs\ (\ rate\ per\ mL\ of\ water) = \frac{mpn}{Seeded\ volume} \times Fd$$

where Fd: the 10^{n} dilution factor for 10^{-n} dilution, $mpn: most\ probable\ number$.

During the isolation of the germs, the use of isolation media was necessary. These media were composed of an elective medium (including fresh blood agar) and two selective media comprising Mac Conkey and Sabouraud. Mac Conkey was conducive to the development of Enterobacteriaceae (Allen, 2005) and Sabouraud to that of fungi (Becton, 2003). The incubation temperature of the Petri dishes containing samples for the isolation was different according to their nature; 35 and 44.5°C for total as well as faecal coliforms, respectively (Centre d'expertise en analyse environnementale du Québec, 2014b). Germ identification was performed on colonies formed during isolation. It consisted in the differential staining of Grams (Gram+ and Gram-), then in tests based on the biochemical reactions between the germs and the constituents of the culture media.

Water pH and electric conductivity of the water were measured

Table 1. WHO physico-chemical and microbiological standards of drinking water.

No.	Parameter	Unit	Indicative value
1	Aluminium	mg/l	0.2
2	Chlorides	mg/l	250
3	Colour	True Colour Unit (UCV)	15
4	Hardness	mg of $CaCO_3$/l	500
5	Iron	mg/l	0.3
6	Total Dissolved Matter	mg/l	1000
7	pH	-	6.5 - 8.5
8	Sodium	mg/l	200
9	Sulfates	mg/l	400
10	Turbidity	Nephrotic Turbidity Unit (NTU)	5
11	Fecal coliforms	Number/100 ml	0
12	Total coliforms	Number/100 ml	0

Source: Weltgesundheits Organisation (1985).

Table 2. Logistic regression models tested.

Model	Dependent variable	Main effects
Model 1	Ability to pay water bills	Profession of household head
Model 2	water sufficiency	Profession of household heads, Municipality
Model 3	Use of water treatment	Profession of household heads, Municipality

Source: Authors

by the electrometric method (Centre d'expertise en analyse environnementale du Québec, 2014a) whereas water hardness or hydrometric titre was measured after Xavier Bataille (2000) and calculated according to the formula:

$H.T = \frac{\text{Drained volume (ml)}}{0.104}$ as described by Kagheni (2016). And to determine the magnesium and calcium contents in these water samples, the relations $Mg^{2+} = H.T. \times 0.0125 \times 200$ and $Ca^{2+} = H.T. \times 0.01 \times 400$ were used, respectively. The measurement of nitrites required reagents composed of Lombard's solution, 1 N hydrochloric acid and 37% NH_4 OH ammonia. The latter was calculated according to the formula (Kagheni, 2016):

$$[NO2-] = \frac{[(D.O - D.O(b)) + 0,0014]}{10,692} \times 20 \text{(mg/l)}.$$

With DO (b) the optical density of the blank and DO the optical density of the sample. In addition, the determination of the nitrate required the Grandval-Lajoux reagents: concentrated H_2SO_4 37 g, phenol 3 g and NH_4 OH so that the total mass is 50 g; the nitrate solution 0.137 g of pure $NaNO_3$ per liter with 0.1 mg of NO_3^- and the silver sulphate solution 4.4 g of Ag_2SO_4 per litre. The nitrate concentration was estimated by the relationship:

$$[NO_3^-] = \frac{[(D.O - D.O(b)) + 0,0056] \times 100}{1,7793} \text{ (mg/l)}$$

of the aforementioned manual with DO(b): the optical density of the blank and DO the optical density of the sample. And to measure the chlorides, the reagents used consisted of pure nitric acid, pure calcium carbonate; potassium chromate solution (10%) and silver nitrate solution (0.1 N). Considering V as the number of milliliters of 0.1 N silver nitrate used for the titration, we then expressed the results according to the formula:

Cl^- content = $Cl - content = \frac{VAgNO3 \times NAgNO3 \times 1000 \times M\ C}{V\ t}$ (test sample).

Statistical analyses

Regarding the physicochemical parameters, the calculated averages were compared with the WHO standards using the Student's t-test of comparison of a single average with the known theoretical average. Thereafter, the principal component analysis (PCA) was applied to the data obtained in order to highlight the similarity and differences between Mount Lubwe springs regarding their physico-chemical and microbial properties. The survey data were analyzed for the determination of the descriptive statistics, to highlight the correlations between the variables studied and multivariate analyses using statistical software R 3.6.1 under R studio 1.2.50001. In addition, the results of water access conditions in households required the use of methods based on the odds *ratio*, using the binary logistic regression (Cibois, 2000). This analysis was carried out using the MASS package and the effects of each variable of the model (OR, confidence interval and significance) were represented graphically using the "forestmodel" package of the R software. The logistic regression models used in the framework of this study are presented in Table 2.

RESULTS

Qualities of Mount Lubwe drinking water

The unilateral Student's t-test of all the measured physico-chemical parameters reveals that the difference between the calculated mean and the WHO standard value is highly significant (p-value < 0.001) except pH (p-value > 0.05). The averages of all these parameters were below WHO standards, which bode well for the good physical quality of water from these springs. The microbiological parameters, however, did not significantly differ from the WHO standards (Table 3). The hierarchical classification (HAC) of this representation is as shown in Figure 2.

The Ascending Hierarchical Classification (AHC) was carried out on five main drinking water springs of Mount Lubwe. It shows three groups of springs based on the results of Principal Component Analysis (PCA). The first group is made up of the ACEKA and ACEKAVU springs and presents non-significantly different values of nitrates and total aerobic mesophilic germs (GTMA) (Table 4) and hence were judged to provide quality water. The second group isolates the springs characterized by a high rate of nitrites (Table 4). Their average nitrite content (0.1245) is significantly higher than the general averages (0.0789). This group includes the Thutwa and Mukohwa springs, which present slightly different soil cover conditions: bare lands and fields for the Thutwa spring and fields with a minority of trees for the Mukohwa spring. The last group discriminates the Ngeleza spring which supplies very poor quality water in view of it microbiological quality; the mean of the variable (45000 UFT/ml) being greater than the general mean (9380).

At the 5% significant level, the "Nitrite" variable is significantly linked to group II whereas the Total Aerobic Mesophilic Germs (GTMA) are associated with group III. Group I is characterized by sources with water suitable for consumption (zero or insignificant total value for total aerobic mesophilic germs and nitrites). Analysis of this table shows that the average of the "Nitrite" variable and that of the "GTMA" variable are each higher than the general average of each group. This means that the sources of group II are characterized by a high content of nitrites while those of group III have a high proportion of total aerobic mesophilic germs.

Access to drinking water in Butembo region

In urban areas of Butembo

With regard to the household head occupation, the ability to pay for an improved service of access to drinking water increases insignificantly for employees of the public sector, those of the private sector as well as traders compared to agents and servants of the state. The logistic regression showed that public sector employees are 2.77 times more likely to pay for the service for water use (OR=2.77). Employees in the private sector are 1.92 times more likely to pay for water (OR=1.92) while traders are 1.84 times more likely (OR=1.84) compared to agents and servants of the state. Moreover, the probability of paying for the improved access to drinking water service decreases sharply among craftsmen (OR=0.41), farmers (OR=0.19) and laborers (OR =0.04) (Figure 3).

Consumers of water from Mount Lubwe have different perceptions of the amount of water available. Adequacy of the quantity of water used in the household are more pronounced among maneuvers, unlike the other professional categories (OR=1.18). The odds ratio associated with farmers is very close to 1, meaning that the professional categories whose household water demand is low (farmers, maneuver), believe that the regularly supplied water is sufficient. The high demand for water in households where the head is an employee of the public or private sector, a trader or a craftsman largely explains the low odds ratios associated with these professional categories (Figure 4). The place of residence in the two municipalities of Butembo (Kimemi and Mususa) did not significantly affect the perception of stakeholders on the adequacy of the quantity of water within the household (p-value=0.09).

The odds ratios associated with the use of water treatment methods before any consumption according to professional categories of the household head were less than 1, indicative of a low probability of water treatment before any domestic use in these categories compared to agents and civil servants of the state. Nevertheless, the analysis of odds ratios reveals that employees in the private sector, the public sector and traders have a low probability of using water treatment methods compared to agent and civil servants of the state regardless the place of residence in Butembo city (Figure 5).

In the peri-urban areas of Mihake and Musienene

In rural areas, there is significantly more chance of finding a teacher or a taxidriver (p-value ≤ 0.05) able to pay bills of domestic water consumption compared to farmers. Considering the age factor, people between 25 and 65 years old are likely to pay for water consumption, whereas septuagenarians (65 to 75 years old) find it difficult to pay the bill for domestic water use compared to people between 18 and 25 (Figure 6).

There was a diversity of opinions on the sufficiency of the quantity of water according to age and professional categories in peri-urban areas. Taxi drivers, butchers, seamstresses, teachers, traders and those responsible for water supply organizations point out the insufficiency of water for domestic use. Only liberals tend to comply with small quantities of water limited to their household needs (Figure 7).

Table 3. Physico-chemical and microbiological parameters of Mount Lubwe water.

Setting	pH	Conductivity (µs/cm)	turbidity (NTU)	HT (°Fr)	NO^{-2} (mg/l)	NO^{-3} (mg/l)	Cl^- (mg/l)	TGMA (N.T.U./ml)	TC (C.S.U./100 ml)	FC (C.S.U./100 ml)	Gram	Isolated germs
ACEKA	7.1	61.7	1.23	4.8	0.043	1.85	1.42	0	0	0	NA	Absent
ACEKAVU	6.13	53.3	1	6.25	0.043	1.5	0.178	300	8	0	Gram-forming bacilli	*Leolercia adecarboxylata*
Tutwa	5.58	90.7	1.2	7.21	0.126	2.703	32.66	900	30	10	Gram-forming bacilli	*Providencia rettgeri*
Ngeleza	5.72	106.4	0.83	11.29	0.06	1.55	16.33	45000	80	20	Gram-forming bacilli	*Ewingelia americana*
Mukohwa	5.71	54.8	1.2	9.61	0.123	0.8	20.59	700	7	0	Gram-forming bacilli	*Aeromonas hydrophila*
Min value	5.58	53.3	0.83	4.8	0.043	0.8	0.178	0	0	0	-	-
Max value	7.1	106.4	1.23	11.29	0.126	2.703	32.66	45000	80	20	-	-
Calculated average	6.05	73.38	1.092	7.832	0.079	1.6806	14.24	9 380	25	6	-	-
WHO standards	6.5	400	5	50	3	50	250	0	0	0	-	-
P Value	0.0901	<0.001***	<0.001***	0.001***	<0.001***	<0.001***	<0.001***	0.352	0.163	0.21	-	-

NTU= Turbidity Unit, HT= Hydrotimetric Titer, TGMA= Total Germs Mesophilic Aerobic, N.T.U = Nephelometric Turbidity Unit, TC= Total Coliforms, C.F.U. = Colony Forming Unit, FC = Fecal Coliforms.
Source: Authors

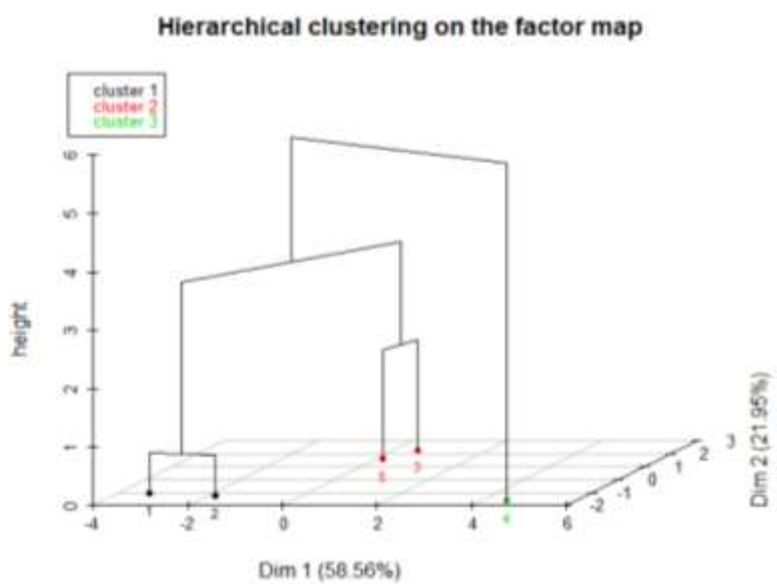

Figure 2. Hierarchical classification of springs based on the physicochemical quality of spring water. 1=ACEKAVU, 2=ACEKA, 3=Thutwa, 4=English, 5= NGELEZA.
Source: Authors

Table 4. Characteristics of groups according to ascending classification based on PCA.

Group	Test value	Mean of the variable	Overall average	Standard deviation of the grand mean	p-value
Group I NULL					
Group II Nitrite	1.97134	0.1245	0.0789	0.03777354	0.0486*
Group III TGMA	1.999693	45000	9380	17812.74	0.0455*

TGMA = Total Germs Mesophilic Aerobic.
Source: Authors

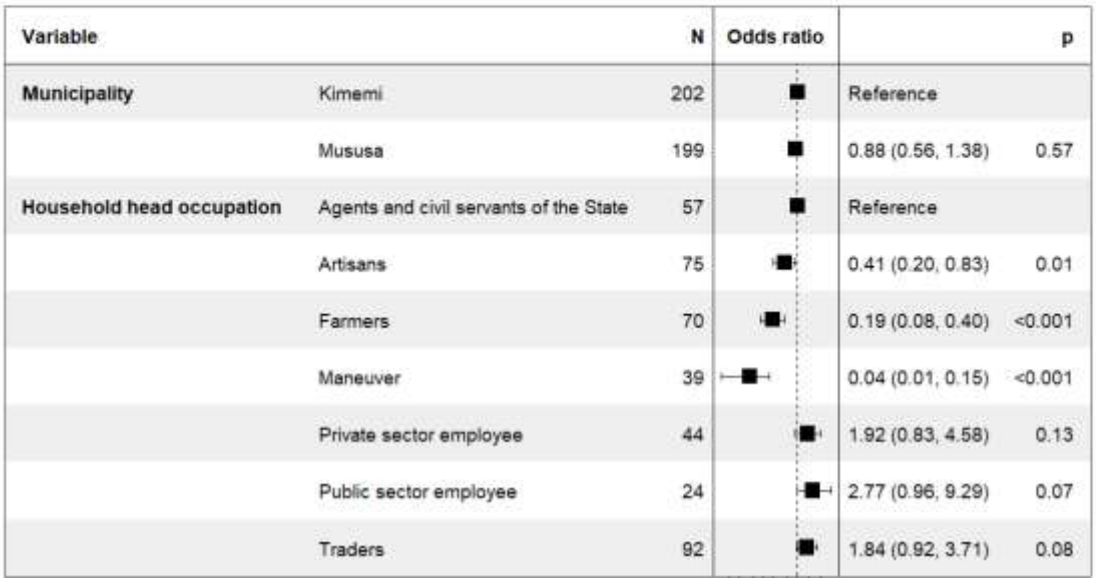

Figure 3. Ability to pay water bills based on the professional category of household head.
Source: Authors

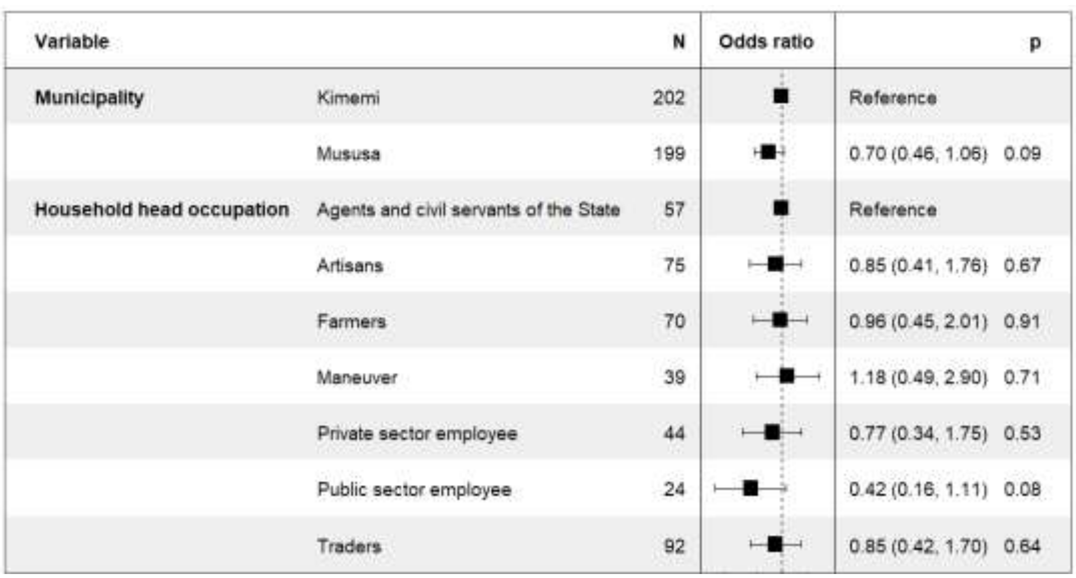

Figure 4. The logistic model of the sufficiency of the quantity of water according to the profession of the head of household and his belonging to a municipality.
Source: Authors

Variable		N	Odds ratio		p
Municipality	Kimemi	202		Reference	
	Mususa	199		0.84 (0.56, 1.27)	0.406
Household head occupation	Agents and civil servants of the State	57		Reference	
	Artisans	75		0.37 (0.17, 0.77)	0.009
	Farmers	70		0.41 (0.19, 0.87)	0.022
	Maneuver	39		0.43 (0.18, 1.01)	0.053
	Private sector employee	44		0.94 (0.39, 2.31)	0.886
	Public sector employee	24		0.50 (0.18, 1.38)	0.175
	Traders	92		0.61 (0.29, 1.24)	0.179

Figure 5. The logistic regression model explaining the perception of knowledge of water treatment methods in the household.
Source: Authors

Variable		N	Estimate		p
Age	Between 18 and 25	6		Reference	
	Between 25 and 35	15		1.10 (-1.75, 3.94)	0.45
	Between 35 and 45	22		0.08 (-2.64, 2.79)	0.96
	Between 45 and 55	17		0.62 (-2.17, 3.41)	0.66
	Between 55 and 65	9		2.02 (-1.28, 5.32)	0.23
	Between 65 and 75	1		-8.27 (-1056.55, 1040.01)	0.99
	Greater than 75	2		-0.13 (-4.28, 4.02)	0.95
Gender	Female	43		Reference	
	Male	29		-2.70 (-5.61, 0.21)	0.07
Occupation	Farmers	29		Reference	
	Butchers	1		-10.52 (-2530.78, 2509.74)	0.99
	Civils servants	3		0.79 (-2.39, 3.98)	0.63
	Dressmakers	4		1.29 (-1.36, 3.93)	0.34
	Liberals	5		-0.42 (-3.62, 2.79)	0.80
	Private employee	4		3.36 (-0.41, 7.14)	0.08
	Responsible for a water supply structure	2		-0.11 (-3.34, 3.13)	0.95
	Taxidriver	3		44.60 (44.60, 44.60)	<0.001
	Teachers	14		4.19 (0.82, 7.56)	0.01
	Traders	7		3.74 (-0.16, 7.64)	0.06
Seniority	5 years	10		Reference	
	Between 5-10	60		-0.21 (-2.05, 1.63)	0.82
	less 5 years	2		-1.76 (-7.87, 4.34)	0.57
quantity	? to 50 liters	31		Reference	
	Between 20 and 50 liters	41		-1.12 (-2.65, 0.42)	0.15

Figure 6. The ability of rural actors to pay for water according to socio-demographic variables.
Source: Authors

DISCUSSION

Quality analyses of the water of Mount Lubwe revealed a high level of nitrates in the Thutwa and Mukohwa springs. The mean of the test was higher than the mean calculated during the analyses. This high rate of nitrites in the water of the springs of Mount Lubwe can be attributed to the influence of anthropogenic agricultural activities carried out in the landscape of Mount Lubwe. In the agricultural neighborhood, the major source of nitrates comes from

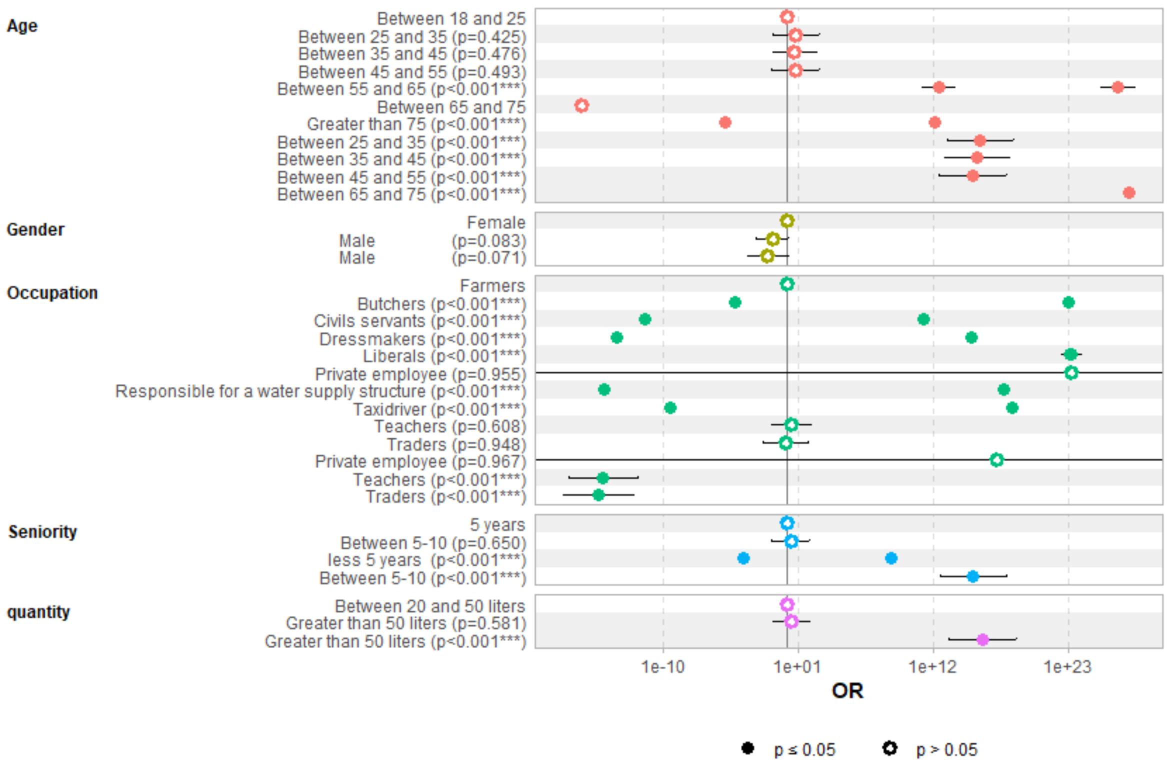

Figure 7. Perceptions of water quantity in peri-urban areas of Mihake and Musienene.
Source: Authors

the supply of nitrogenous fertilizers (Collectif Lanutrition.fr, 2008). They can, where appropriate, come from domestic and industrial effluents as well (slaughterhouses, tanneries, etc.) (Festy et al., 2003). The high level of nitrates in drinking water has health consequences for consumers; like the potentially carcinogenic effects (Juneau, 2018). However, “health objectives are among the key components of the framework intended to guarantee water safety” (WHO, 2017). Nitrites with other nitrogenous compounds (N-nitrosamines) can damage genes and cause cancers (oesophagus and stomach) in all animal species (Collectif Lanutrition.fr, 2008). Moreover, its excessive ingestion also reduces the ability of red blood cells to bind and transport oxygen in children (Observatoire régional de la santé Rhône-Alpes, 2007).

However, the WHO (2004) asserts that the vast majority of obviously water-related health problems result from microbial contamination. Hence, there is reason to fear for the health of consumers of the waters from the Ngeleza spring. For this spring, the number of total aerobic mesophilic germs was higher (45000 UFT/ml) than the general threshold value (9380 UFT/ml) and that of the WHO (0 UFT/ml). The presence of germs would be partly linked to the absence of tree cover around the Ngeleza spring. In fact, plant cover in general and forests in particular play an important role in reducing bacterial loads in water as well as heavy metals (Calder et al., 2007). On the other hand, it would be associated with the existence of contaminants from human and animal waste, given the strong demarcation of human presence in the ecosystem of Mount Lubwe reflected in the activities of agropastoralism and the charcoal production. Most of the microbial and parasitic pollution of water originates from the fecal waste (Festy et al., 2003). This decreases the intrinsic quality of water as asserted by Neuchâtel (2007) for that of foodstuffs. Also, the identification of other germs in the water such as *Providencia rettgeri, Aeromonas hydrophila, Ewingelya americana,* and *Leolercia adecarboxylata* is a tangible proof of some pollution for the sources of Mount Lubwe. Most of these contaminants are bacteria that can, in some cases, cause gastroenteritis in children (Marisol, 2010). For instance, *A. hydrophila* infection can lead to gastrointestinal or non-gastrointestinal complications; symptoms for this infection ranging from watery diarrhea to dysenteric or bloody diarrhea and a possibility, if present, of a chronic infection” (Public Health Agency of Canada, 2010).

“Water not only satisfies basic human needs, but also contributes to sustainable development” (WHO, 2017). However, a marginalization in the access to this vital resource is increasingly observed as was the case in the present study with regard to results of the conditions of access to water in the various study sites in the Butembo region. Only people with a stable income (civil servants, merchants, employees) are able to pay their water consumption bills. Low-income social categories (farmers and craftsmen) find it difficult to pay the bill for domestic water use. This situation would be due to the irregularity of income among people of the poor category because water weighs more in the budget of poor households than that of rich households (Smets, 2000). It might also be due to a low level of savings for these households. A similar situation was observed in West Africa where Savina and Mathys (1994) demonstrated that household financial demand and ability to pay money for water only made sense among high-income people and those who can regularly have enough to save (Savina and Mathys, 1994). Furthermore, it is recognized that water consumption increases with household income, but less rapidly than income (Smets, 2000). The social categories with modest incomes from the two areas (rural and urban) have recognized that the quantity of supplied water is sufficient; with a large number of alternative sources in the Butembo region. This situation could be explained by the price of water, which is already rising in both areas. In Butembo, water consumption costs have risen from 3 to 15 US dollars per year and per household, obliging them to resort to alternative sources of water. This shift to alternative sources raises concerns to the WHO (2004) which points out that “the high cost of water can lead people to resort to other sources of lower quality; representing high health risks. It can also lead to a reduction in the amount of water to be used per household”; leading them to self-satisfaction. Moreover, the lack of vehicles, gardens and other infrastructures using water in large quantities would plead of the low water consumption among people in the poor category. In fact, apart from the number of people in the household, sanitary facilities, income and climate which affect the quantities of water to be used, water consumption also varies according to hygiene habits, the life style and/or the presence of the garden in the household (Smets, 2000). However, the results revealed that during shortages the population resorts to many alternative sources of the urban area in Butembo but of dubious quality, majority being traditional wells. Musavandalo (2016) in his study on access to drinking water in Butembo city demonstrated that REGIDESO, the main water supplier in the city, is unable to keep up with the rapid spread of urban space. As a result, the REGIDESO only serves a handful of the population in the central part of Kimemi municipality with water of dubious quality. This exposes the health of the population; the prevalence of waterborne diseases being real in the city.

The question that must currently arise between the drinking water supplier in the Butembo region and the forest managers is to know to what extent this water tower on Mount Lubwe will continue to offer water in quantity and in quality to the close and distant beneficiaries. This is important in view of the degradation of the quality of the supplied water, the anthropization of the landscape and the low willingness to pay for an improved service of access to drinking water. One strategy would be to determine the full economic value of the water storage function of Mount Lubwe in order to clearly define the strategies for its management and compare the latter to the economic value linked to the exploitation of forest resources of Mount Lubwe.

CONCLUSION AND RECOMMENDATIONS

Water is life. But water can be a source of death if it is contaminated. With the aim of checking the compliance of Mount Lubwe's water quality with the standards of the World Health Organization (WHO) as well as determining the access conditions in the urban and periurban areas of Butembo region, it appears that the different modes of use of the resources of Mount Lubwe have negatively affected water quality of the springs of this mountainous ecosystem. The increase in the rate of nitrites and germs in the water is real in the Thutwa, Ngeleza and Mukohwa springs. Furthermore, the conditions of access to water in the area generally reflect a marginalization in the ability to pay for.

These findings lead to the following recommendation:

(1) Creation of buffer zones around springs in order to prevent the nitrous and microbial contamination;
(2) The establishment of a concerted management framework involving all actors (customary chiefs, the state, communities, etc.) would also be promising.

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