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The Bacteriological Quality Of Water From Alternative Sources In Bukavu, Democratic Republic Of Congo

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Abstract: Bukavu, the capital city of the South Kivu province, is a growing city due to rampant demographics and rural exodus aggravated by rural insecurity. With around 1 million inhabitants, it faces a decade of water scarcity exacerbated in the dry season following the unability of the state company to provide drinking water to the whole city. Households draw drinking water from sources below the neighborhoods, in Lake Kivu or in the Ruzizi River, with the consequences of the high prevalence of waterborne diseases including cholera. This study was conducted in order to determine the bacteriological quality of water from these sources and the contamination factors. In may 2018. water samples were collected from 49/76 existing sources selected at random. The analysis was conducted in the light of the WHO guidelines on water quality. Samples were collected in Whirl Pack bags and analyzed in the Panzi General Hospital laboratory. Total forms of Coli were isolated and enumerated using membrane filtration technique and growth on the membrane lauric sulphate (MLSB) broth while the MacConkey broth was used for isolation of Escherichia coli, and the TCBs Agar for the isolation of the Vibrio cholerae. The results show that water from almost all the alternative sources in Bukavu is unsafe for drinking because they are contaminated by Escherichia coli (94%) and vibrio cholerae (22.4%).The risk factors for contamination are anarchic constructions, undeveloped and unprotected sources from human or animal fecal material. To cope with this, the provincial government and its partners should intensify awareness on the need to boil or purify water from these sources before consumption and consider the development of some sources while waiting for a definitive solution.

Key word: Congo DR, drinking water quality, contamination factors

INTRODUCTION

Access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection [1]. Access to drinking water and sanitation is the sixth objective of the sustainable development of the 2030 agenda that was adopted by the United Nations in September 2015 (UN) [2]. Like other developing countries, access to sanitation and water supply are often inadequate in the Democratic Republic of the Congo (DRC). The last Demographic and Health survey has shown that 51% of Congolese households get water from unimproved water sources, in particular unprotected sources (36%) and 9% drink surface water [3]. Bukavu, the capital city of South Kivu province is located on the south-west shore of Kivu Lake. Of mountainous terrain, it is built on an area of 60km^2, and inhabited by around 1milion residents (2016),with a density of 14 000habitants per km^2 [4] . From a decade, the damaged infrastructure, the long years of underinvestment, rural exodus from the persistent insecurity in rural areas and the rapid growth of the population has declined the coverage rate of water supply by the state company, Regideso, especially in the dry season. To deal with the shortage, many households fetch water from springs, wells, Kivu Lake and the Ruzizi River. Thus, the city has experienced a cholera epidemic and drowning cases. In 2017 it recorded 2228 cases of cholera from week 1 to week 52 departed in the three health zones with 1090 cases in the Ibanda area, 623 cases in the health zone of Kadutu and 515 cases in the health zone of Bagira [5].Currently, the degree of contamination. of these alternative water is unknown. The objectives of this study are to examine the bacteriological quality of the are to examine the bacteriological quality of the water from the selected water sources and to determine the water the factors of water sources contamination.

METHODS

Study environment

The study was conducted in the three urban districts of the city, which also correspond to the three health zones, namely Bagira, Ibanda and Kadutu.

Research approval.

The current research about the water quality analysis in Bukavu was approved by the provincial Ministry of Health, Social affairs, Gender, Child and humanitarian affairs. Data collection was restricted to sampling from water sources other than state supplied by the State Company. Hence, the staffs from the ministry were involved in data collection from springs and wells. We then, shared the results with all actors: State services, universities departments and nongovernmental organizations involved in the Water, Sanitation and Hygiene in the South Kivu Province.The list of springs and wells was obtained from the Health Zone offices. Apart from Kivu Lake and the Ruzizi River, Bukavu has 76 water sources including the so-called Bizola makeshift wells. 49 water sources were selected using the table of random number.

Samples' Collection
The collection of samples was carried out by two experts from the Office of Hygiene and Public safety of the provincial health Division and one staff from Congo Relief and Integrated Development association (CRID). A total of 98 samples or 2 per water source were collected from May 12 to May19, 2018. It was at the last month of the rainy season. An average of 20 samples per day was collected in a special sterile water collection bag of 100ml, brand WHIRL PAK THIO-BAG containing thiosulfate sodium. They were directly labelled, water, source name date, time of collection by the indelible marker, and then stored in an accumulator cooler between 6-8^{o}C and transported before 3p.m to the laboratory. A collection form has been regularly completed by the investigators, taking the name of the source, date and time of withdrawal.

Measurement of PH, turbidity and conductivity at the site
The temperature and PH of the water were measured using a PH/temperature counter of the WTWÒ microprocessor, previously calibrated with ph 4 and 7 using standard buffer solutions according to the manufacturer's instructions (WTW, Vienna, Austria).

Measure of turbidity.
The turbidity was measured by the Spectrophotometer HACH DR/2010Ò. 25 ml of a well-mixed sample were

Laboratory analysis
Laboratory analyses were carried out in the Department of Microbiology of the laboratory of the Panzi referral Hospital, located at 7km south from the Bukavu city centre. The bacteriological parameters analyzed were the detection and enumeration of total coli forms, Escherichia coli, and Vibrio cholerae. Total forms of Coli were isolated and enumerated using membrane filtration technique and growth on the membrane lauric sulphate (MLSB) broth. The sample was filtered and the membrane was then placed on an absorbent pad soaked in MlSB. The plates were then incubated for one hour at room temperature to facilitate resuscitation and incubated for 23 hours at 37 °c. All yellow colonies on the membrane were counted using a magnifying glass and recorded as presumptive total coli forms. For confirmation, a representative number of characteristic yellow colonies were under cultivated in tubes of shiny green bile broth (BGB) and incubated at 37 °c for 48 hours. The production of gas in the BGB broth confirmed the presence of coli forms. The results were then expressed in number of colonies in 100 ml of the original sample as described by APHA. [6]

Isolation of Escherichia coli
The isolation of Escherichia coli was made on MacConkey broth sucrose (BMS) by the transfer of 0.1 ml of the sample to be analyzed and its decimal dilutions to the surface of the medium prepared in cans. The inoculums were then surface-spread using a sterile display and incubated at 37 °c for 24 hours. The production of gas in the broth confirmed the presence of thermo-tolerant coli forms. Red colonies of different sizes extending over the membrane were counted using a magnifying glass and measured into a clean sample cell. Another sample cell was filled with distilled water. The intensity of light scattered and absorbed by the sample was compared to that measured for standard formazin suspensions and was read at a wavelength of 860 nm. We did not measure chemical components in the water. culture of vibrio cholerae and other Vibrio species. The filtrate was inoculated on TCBS agar medium and incubated at 37 °c for 24 hours. After incubation, the yellow colonies of vibrio cholerae were observed, counted. The number of/100ml colonies in the sample were recorded.

Assessment of contamination's risk factors
The key factors were those used by Rukia et al [7]:
1 = Spring unprotected;
2 = Masonry protecting spring faulty;
3 = Backfill area eroded;
4 = Spilt water floods collection area;
5 = Perimeter fence absent;
6 = Animals have access within radius 10 m of spring;
7 = Pit-latrine uphill and/or within 30 m of spring;
8 = Surface water collects upstream of spring; 9 = Diversion ditch above spring absent/non-functional 10. Other pollution sources uphill of spring e.g., solid waste dumps, faeces, stagnant water, and drainage channels.

These variables were observed by the survellers using a form and giving a score for each variable.

taken to be thermo-tolerant coli forms. Red Pink (Escherichia coli) colonies were counted.

Isolation of Vibrio cholerae.
Vibrio cholera was isolated by culture on the medium of Thiosulfate Citrate Bile Salt sucrose Agar (TCBS Agar), a selective differential medium used for the isolation and

Data analysis
The data were entered in Microsoft Excel programme and descriptive statistics were computed. Statistical tests were performed using SPSS programme. The Pearson product-moment correlation coefficients for contamination and sanitary risk factors score and the median counts of total coli forms, faecal coli forms and faecal streptococci were computed. The bacteriological counts recorded were compared with the WHO guidelines for drinking water.

RESULTS
Table 1 and II shows the bacterial indicator levels of organisms in water from the sources studied. Almost all sources are contaminated as indicated by isolated bacteria, with a variation of microbial level in among different water sources.

a) The total coliforms varies from 150 to 80 000TC /100ml.The number of total coli forms>100/100ml has been found in 93,8 % of samples, or 46/49 of water sources,
b) The number of faecal coliforms varies from 50 to 60.080 CF/100 ml. 47/49 sources or 95.9% of the samples had faecal coliforms beyond who standards for drinking water. The enumeration of Escherichia coli ranged from 600 to 4500EC/100 ml. Wells (Bizola) Chemu1/Nguba, John Miruho 1 and 2, and Irambo had a higher mean of Escherichia coli

bacterial indicator. There was no significant difference (P = 0.501) between the average of the counts of Escherichia between the sources of the different zones.)

c) The isolation of Vibrio cholerae.

This was present in samples from 11 sources, and then, or 22.4%, namely:

-In the health zone of Ibanda These are the wells Cemu1 of Nguba, Bizola Jean Miruho 1 and 2 and the source of Kapapa,

-In the health zone of Bagira, these are samples from the water sources of Chemu Chula- Burhiba and the source Wesha 5 of Charahabe.

-In the health zone of Kadutu, these are the water sources Nyakaliba ITFM, Cheche, Mulehe and Texas.

Table 1. *Distribution of water source per bacteriological statuts in Bagira and kadutu health zones*

Health Area	Water source	Total CF/100ml	E. Coli/100ml	Vibrio Cholera/100ml
BAGIRA district				
Nyamuhinga	Musigiko	>10	0	0
	Nyakavgo	1250	1300	0
Burhiba	Chemchula	4300	1700	>100
	Mugenge	1100	1300	0
	Mulimlimbi1	2100	1400	0
	Mulimlimbi2	2250	1500	0
Mushekere	Wesha Chabarabe	4600	1800	>100
KADUTU District				
CEPAC BUHOLO	Cam Régie	4200	1200	0
	Mulehe	3200	2200	>100
	Nyamiera	4200	1200	0
CIRIRI	Makoma	4200	2100	0
	Irhenga1	4250	1300	0
	Irhenga2	4200	1500	0
MARIA	Texas	4200	1500	>100
	Ngabo	4150	1200	0
	Wesha	4200	1700	0
	Wesha1	>10	0	0
	Wesha2	3800	1800	0
	Wesha3	4200	1300	0
	Washa4 Kaba	4200	1200	0
Funu1	Funu	4200	1100	0
Funu2	Pas à pas	2650	800	0
Camp Mweze	Kadurhu	4200	900	0
	Nyakaliba ITFM	1300	800	>100
	Bijabwa	2300	1100	0
CBCA Nyamugo	Nyamugo BCB	>10	0	0
	Fariala	1550	800	0
Uzima	CC Cheche	3850	2300	>100
Ibanda district				
NYAWERA/FARDC	Kwamutu Magambo	2300	1200	0
	Cercle hipique	2350	1200	0
IRAMBO	Byaene	2100	1100	0
	Beatitude	1600	2700	0
PANZI	JMirugho1	4550	3300	>100
	JMirugho2	4600	3700	>100
	Kabangere	5600	1700	0
	Mushununu	5700	1300	0
KABUYE	Kapapa	5700	1900	>100
	Kaliba1	3800	1700	0
	Kaliba2	3700	1200	0
Muhungu celp	Sapinière1	3600	1100	0
	Sapinière2	5400	1700	>100
CIHAMBA	Gihamba	1200	800	0
CRge Nguba	Shaba II	5800	2700	>100
	Chemu1-Nguba	5450	2000	>100
	Mande	4200	2300	0
	Bazee	4200	2800	0
CIDASA	Luganda	4150	2700	0
	Chemu1 kaza	4200	2800	0

Assessment of contamination risk factors.

The table blow shows that all the sources present high level of contamination risks. Only these sources of Musigiko, wesha 1 and Nyamugo BCB are those at low contamination risk.

Table 2. *Table III. Sanitary risk assessment of water sources in Bagira, Ibanda and Kadutu.*

no	Health area	Water source	Score Risk observed	% score	Qualitative Risk profile
1	Nyamuhinga	Musigiko	3, 5	20	low
2		Nyakavog	2 -9	70	high
3	Burhiba	Chemchula	1-10	100	high
4		Mugenge	1-10	100	high
5		Mulimbil1	3-10	70	high
6		Mulimbil2	3-10	70	high
7	Mushekere	Wesha Cha	1-10	100	high
8	Cepac Buholo	Cam Régie	1, 2-10	90	high
9		Mulehe	1-3,5-10	70	high
10		Nyamiera	1, 2-10	90	high
11	Ciriri	Makoma	1-3,5-10	70	high
12		Irhenga1	1-3,5-10	70	high
13		Irhenga2	1,2,5,6,8,10	60	high
14	Maria	Texas	1, 2-10	90	high
15		Ngabo	1,2,5,6,8,10	60	high
16		Wesha	1,2,5,6,8,10	60	high
17		Wesha1	1,5	20	low
18		Wesha2	1,2,5,6,8,10	60	high
19		Wesha3	1,2,5,6,8,10	60	high
20		Washa4	1,2,5,6,8,10	60	high
21	Funu1	Funu	1,2,5,6,8,10	60	high
22	Funu2	Pas à pas	1, 2-10	90	high
23	Camp Mweze	Kadurhu	1,2,5,6,8,10	60	high
24		Nyakaliba	1, 2-10	90	high
25		Bijabwa	1,2,3,5,8,9	60	high
26	Cbca Nyamu.	Nyam. BCB	5	10	low
27		Fariala	1,2,4,6,8-10	80	high
28	Uzima	Cc cheche	1,2,4,6-10	90	high
29	Nyawera	Kwamutu	1,2,4,6,8-10	80	high
30		cercle hip	1-10	100	high
31	Irambo	Byaene	1-10	100	high
32		Beatitude	1-10	100	high
33	Panzi	JMirugho1	1-10	100	high
34		JMirugho2	1-10	100	high
35		Kabangere	3-9	70	high
36		Mushunun	3,5-9	60	high
37	Kabuye	Kapapa	1-10	100	high
38		Kaliba1	2,5,6,7 ,8,9	60	high
39		Kaliba2	2,4,5-10	80	high
40	Muhungu	Sapinière1	2,4,5-10	80	high
41		Sapinière2	1-10	100	high
42	CIHAMBA	Gihamba	1-10	80	high
43	Nguba CR	Shaba II	1-6,9,10	80	high
44		Chemu1N	1-5,7-10	90	high
45		Mande	1-5,7-10	90	high
46		Bazee	1-5,7-10	90	high
47	CIDASA	Luganda	1-5,7-10	90	high
48		Chemu1 ka	1-5,7-10	90	high
49		Chemu2 ka	1-5,7-10	90	high

Contamination risk factors

III.2. Correlation of bacterial counts and the sanitary risk score

The Pearson correlation coefficient of median total coli form counts with the sanitary risk score was 0.885, the median faecal coli forms with the sanitary score was also 0.888, while that of median Escherichia coli with the sanitary score was 0.795.

Sanitary risk assessment of water sources.

Table III presents the results of the observed risk assessment. All 49 water sources studied were at risk of being contaminated by bacterial faecal organisms. The qualitative aggregate risk score varies from medium to high. Thus, 47/49 water sources or 96% had a very high risk score (81 to 100%), while only 2/49 water sources or 4% had an average risk score (31-50%). No water source had a risk score of 0. The common risks identified are: the non-development, the presence of pit latrines within a radius of less than 20m, the presence of sources of pollution such as solid waste, inadequate sanitary protection measures such as the absence of closure and the absence of bypass ditches.

DISCUSSION

Water quality assessment is the overall process of evaluation of the physical, chemical and biological nature of the water, whereas water quality monitoring is the collection of the relevant information.[8] Monitoring of water quality to ensure microbiological and chemical safety is a vital public health function especially in developing countries.[9] The bacteriological analysis of alternative water sources in this city have shown a high

level of contamination with 93.8 % of water sources having more than 1000 total coli forms per 100ml (Table II). This is much higher than the rates recommended by WHO on drinking water quality. Indeed, the WHO recommendations for bacteriological quality of drinking water are 0 faecal Coli form and 0 total Coli forms per 100 ml. [10] In this study, the highest level of contamination was found in boreholes, especially those called Bizola. Similar results have been found in Cameroun and in Kenya [11, 12]. Our study found that 95.9% of water sources were contaminated with more than 1000 Escherichia Coli/100ml (Table II). This clearly indicates the faecal contamination of sampled water sources in Bukavu city and the possible presence of other faecal-source pathogens and micro-organisms [13]. As it is relatively easy to identify Escherichia Coli compared to other indicators or specific pathogens, it has been commonly accepted as a useful specific indicator of faecal contamination [14]). The current situation of Bukavu city is typical of other DRC towns and cities, with high contamination by bacteria from human origin [14, 15, 16].Several other studies have found Escherichia coli plus other pathogen bacteria while studying drinking water quality, especially streptococcus, Salmonella and Proteus in water samples, with species richness varying from one water point to another [17, 18]. Although this study did not test for these additional pathogens, they are likely to be present given the high level of faecal contamination found in water sources' samples. Escherichia coli is a fecal coliform commonly found in the intestines of animals and humans, that are associated with human or animal wastes[19], its presence in water is a strong indication of recent sewage or animal waste contamination and suggests that other disease-causing bacteria, viruses, protozoa may likely be present [20]. Escherichia coli strains O157:H7 and E. coli O111 cause bloody diarrhea indistinguishable from hemorrhagic colitis. Between 2% and 7% of cases develop the potentially fatal hemolytic uremic syndrome, which is characterized by acute renal failure and hemolytic anemia. Children under 5 years of age are at most risk of developing hemolytic uremic syndrome [21]. Waterborne transmission of pathogenic E. coli has been well-documented for recreational waters and contaminated drinking-water [20,21]. The presence of vibrio cholera in 22,4 % of water sources samples (Table II) is further evidence of high contamination of water sources in Bukavu and explains the recurrent episodes of cholera that has become endemic. Previous study during cholera epidemic in Uvira town has shown that the suspected cholera incidence rate increased on average by 155% following a day without water tape, while suspected cholera cases attributable to a suboptimal tap water supply reached 23.2% of total admissions in Cholera treatment center [22]. The rate of contamination of our water sources by vibrio cholerae is lower than those found in Cameroun and Bangladesh where positive samples with vibrio cholera was respectively 27, 4% and 38% [23,24] Despite of the various of contamination rate of the sources, the link between the presence of cholera and contamination of water sources or water tanks has been established [25, 26]. In the present study, the correlation between median total Coli form and Escherichia Coli counts with the source sanitary score showed that it is a reliable tool for preliminary risk assessment of spring water contamination with faecal bacteria organisms. In fact, 96% of the water sources sampled were unprotected. The open wells exhibited the highest levels of contamination and they have no protection, being accessible by animals and polluted by rainwater runoff as found in Port Harcourt Nigeria and Monrovia, Liberia where faecal contamination was highest in unprotected open wells, and higher than water from water taps and sachets [27]. Unprotected water sources wells have often shown higher levels of contamination in rainy season [27, 28]. According to the UNICEF, in 2015, 159 million people still collected drinking water directly from 58% lived in sub-Saharan Africa [29]. Howard (2003), stated that the high risk of contamination of water sources by pathogens and harmful chemicals is due to increasing population density, lack of adequate sanitation infrastructure, and poor construction [30]. Also, unsafe storage is the major source of water born diseases hence they are mostly overlooked by water professionals [31]. In Bukavu, the presence of high contamination of water sources is explained by the increased of risk factors, including the invasion of springs by runoff carrying mud and waste of all kinds, including faeces. The anarchic construction in addition to the weak management system of waste of waste increase the risk of contamination of water sources in this town. With inadequate household sewage disposal, it is not surprising that unprotected wells and springs have a high degree of fecal contamination. Poorly planned construction of toilets upstream from spring water construction on one hand, residents to be aware on their role in managing their waste and maintaining a clean environment around water sources on the other hand. Poorly planned construction of toilets upstream from spring water sources, contaminate groundwater. Although we did not do any water quality testing of the REGIDESO pipe network, other studies have suggested the contamination of pipe delivered water due to leaks in the pipe system. [31, 32] The link between the risk assessment score and the contamination of 47 water sources, support the statement that sanitary risk assessment score is a reliable tool for predicting the likely levels of bacterial contamination of spring water[7,33]. Without treatment or development of these sources, they remain unsafe for human consumption. To make them safe requires the urban and municipal authorities to regulate and improve construction on one hand, residents to be aware on their role in managing their waste around waters sources on the other hand. The limitation of this study includes the none comparison between the rainy and the dry season, the none detection of other bacterial species associated with water contamination from the samples, and no chemical analysis compared to other similar studies.

CONCLUSION AND RECOMMENDATIONS

This study showed the contamination of almost all the water sources' samples with faecal coli form. 95.9% contained Escherichia Coli while 22.4% contained Vibrio Cholera. Thus, water from these alternative sources is unsafe for human consumption and presents a high health risk. Disinfection such as boiling, chlorination, or using UV ozonization is essential before consumption. The government water supply authority, REGIDESO, needs to

be adequately resourced to carry out repair and expansion of the Bukavu water supply network to meet the needs of the expanding population of the city. As an immediate short term measure, the Ministry of Health should establish disinfection measures at the contaminated source sites, and water users need to be sensitized to the importance of boiling source water before consumption. Health Zone officials can play a key advocacy role towards local authorities and international development partners for funding new water sources and rehabilitation of existing sources.

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