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(Research Article)

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Physico-chemical analysis of rainwater stored in cisterns for consumption in the Nyiragongo territory (RD CONGO)

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Abstract

The aim of this research is to assess the quality of rainwater stored in cisterns in Nyiragongo territory in order to prevent pathologies among the population. The various household surveys were complemented by an analysis campaign. Twenty-five (25) cisterns were targeted, making it possible to assess the bacteriological and physico-chemical quality of the water stored for actual use. Household surveys revealed a lack of hygiene around the cisterns. Of the twenty-five water samples analyzed, only two were free of any contamination.

The conclusion is that the consumption of rainwater exposes the population of Nyiragongo territory to water-borne diseases such as gastro-enteritis and many other pathologies. However, given the difficulties these inhabitants face in accessing sources of drinking water, and thanks to the non-turbid state of this water, it can be consumed after prior treatment with chlorine and/or zonation.

Keywords: Cistern (Tank); Physico-Chemical; Bacteriology; Health Risk; Nyiragongo

1. Introduction

Water is essential to life on Earth; it is the major component of the human body and has enjoyed sacred status in many civilizations. [J. Hospitalier-Rivillon, et al., 2008]. Water is a precious natural resource, essential for many uses (domestic, industrial and agricultural). Water is a natural resource essential to life in any ecosystem [Tampo et al., 2015]. Maintaining its quality is a major concern for a society that has to meet ever-increasing water needs [Foto et al., 2011]. Water plays a key role in socio-economic development at local, regional and national levels. [Talhaoui A., et al., 2020].

- Its quality is a factor influencing health and mortality in both humans and animals [Kazi et al., 2009].
- Because of its vital nature, the water consumed must be of good sanitary quality in order to avoid the occurrence of waterborne pathologies. [Nimri L., et al., 2004].
- Access to quality drinking water is a public health priority. [MUTONKOLE N, et at., 2025]

Its availability and quality are major issues for socio-economic development, particularly in developing countries. While in industrialized countries access to drinking water is generally assured by modern supply networks, this situation remains largely unsatisfactory in many parts of sub-Saharan Africa, where a significant proportion of the population still relies on untreated water from hand-dug wells, streams or rainwater harvesting [Howard, G., and Bartram, J., 2003 , Lagnika, C., et al., 2014].

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Water pollution, defined as physical, chemical or biological degradation caused by human activity, disrupts aquatic life conditions and balances compromising their multiple uses. [Sadat AW et al., 2011]

In most developing countries, due to lack of resources, quality control and monitoring of surface and groundwater used for drinking water production are not systematic. [Sadat AW et al., 2011]

Drinking water is water that is suitable for consumption by living beings. It must be free of all pathogenic micro-organisms and toxic substances harmful to human health. It must meet strict potability standards and WHO guide values [BLIEFERT et PERNAUD ,2001].

Although access to drinking water and sanitation is now recognized as a fundamental right by the international community, inequalities persist from one environment to another. One billion people still have no access to drinking water, and over two billion to sanitation. Water, as a vital resource for human life, is now the focus of public authorities' concerns for its sustainable management. However, although this resource is essential to life and human development on earth, it poses problems of exploitation, management and quality everywhere in the Third World [OMS, 2005].

In the Democratic Republic of Congo (DRC), the drinking water supply provided by Regideso, the national water company, does not cover the entire territory, particularly in certain outlying urban areas.

Water is a ubiquitous, colorless, odorless and tasteless chemical compound that constitutes a fundamental element in the life of living beings, often used as an excellent solvent in the composition of the majority of organisms and an essential element for multiple uses [BERNARD, 2007].

In the Democratic Republic of the Congo in general, and more specifically in North Kivu, in the city of Goma in the Nyiragongo territory, REGIDESO, a state institution responsible for treating and distributing drinking water to the population, has probably failed in its missions due to the total shortage in this area, yet there is galloping demographic growth characterized by waste production and water pollution. This pollution is linked not only to population growth but also, and above all, to the gases emitted by the Nyiragongo volcano, which reduces the quality of water intended for consumption. Lack of hygiene and consumption of water contaminated by microbes are responsible for around 85% of deaths. The WHO estimates that 80% of illnesses in developing countries are linked to poor water quality, and that one African in two suffers from a waterborne disease. Microbiological analyses based on the search for bacteria are considered to be indicators of faecal contamination. The Nyiragongo territory, where the study was carried out, does not have any watercourses or springs. In view of the above, it is very important to evaluate the water storage and supply cisterns, their threats and to know the results of the analyses of the water used in the Nyiragongo territory. A similar study had already been carried out by DOVONOU et al. (2020) in the Toffo commune in Benin, with the same results.

The aim of the present study is therefore to identify the enterobacteria in rainwater used by the inhabitants of Nyiragongo territory that are likely to be harmful to human health, and to identify them by bacteriological analysis.

2. Materials and methods

2.1. Study site

Nyiragongo territory is an administrative entity in the eastern part of North Kivu province in the Democratic Republic of Congo. It comprises a single chiefdom headed by a Mwami, divided into 7 groupements and 58 villages. Its chief town is Kibumba. It covers an area of 333km2, with a population density of 438 inhabitants/km2, and its geographical coordinates are: 1°30'36''South and 29°14'39'' East (Fig. 1).

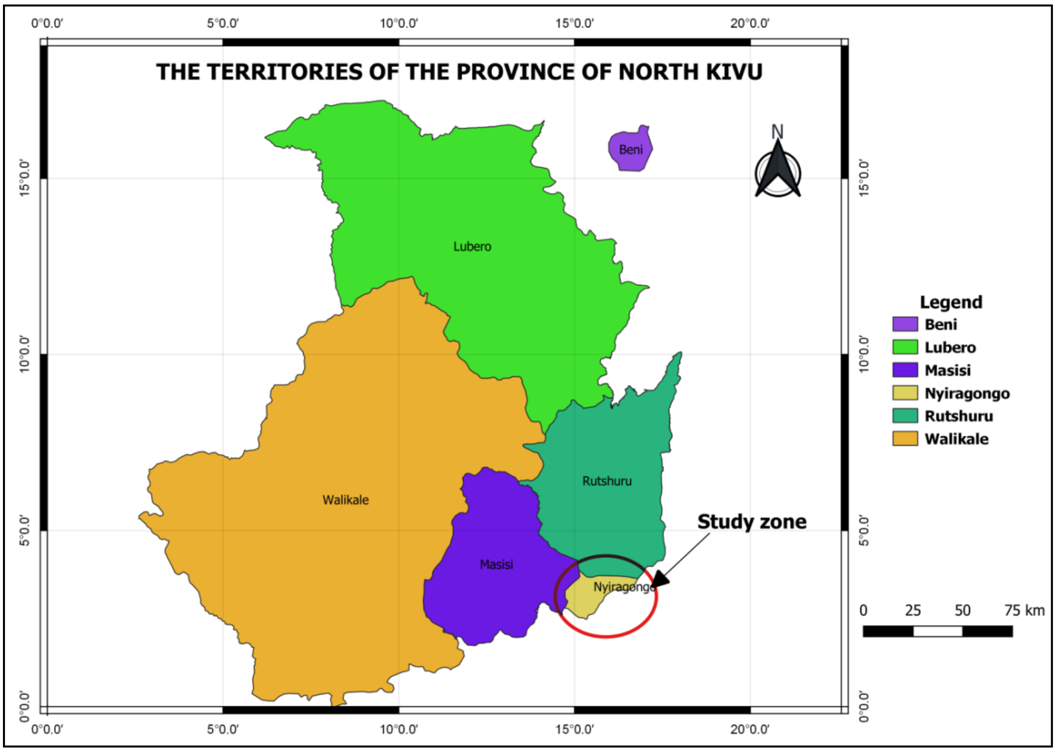

Figure 1 Geographical location of Nyiragongo Territory [Faustin S. Habari et al., 2022]

2.2. Water sample preparation and analysis

Twenty-five cistern water samples were taken between February 2023 and April 2023. Sampling was based on traditional cisterns or wells containing rainwater. Samples for physico-chemical analysis were taken in sterilized 1.5L bottles. Bacteriological samples were taken in sterilized 500 ml emery-stoppered borosilicate brown glass bottles. These bottles, which are not filled to the brim, are cleaned, labeled and placed in a cooler for return to the laboratory.

*Physico-chemical analysis: Physico-chemical parameters include pH, turbidity and temperature.

*Bacteriological analysis: Bacteriological analysis began the same day, 2 hours after sampling. Samples were stored in a refrigerator at 5°C until interpretation was complete. Carried out in the same laboratory, these analyses included total germ counts, E. coli and fecal coliforms. Coli bacteria and fecal coliforms. For the detection and enumeration of total germs, work was carried out in accordance with standard NF EN ISO 6222 of 07/99. One milliliter (1 ml) of water from each sample was taken to hydrate a 0.45 µ diameter Petri film membrane. The membrane was incubated at 37°C. Red colonies were counted 24 hours after incubation. For E. coli detection and enumeration, the standard NF EN ISO 9308-1 of 09/00 was used as a reference. One milliliter (1mL) of water from each sample was taken to hydrate the E. Coli Petri film. After filtering 100 ml of water from each sample through a membrane, the membrane was applied to the Petri film. This time, incubation was carried out for 48 hours, still at 37°C. Results were interpreted and analyzed in accordance with WHO guidelines.

3. Results

3.1. Spatial layout of cisterns

This survey enabled us to visit one hundred (100) households, including four (4) per village, and two (2) people per household were interviewed in order to obtain more information on the use of cistern water.

The aim of the survey was to identify factors that can affect the quality of cistern water. The table below shows the distribution of cisterns visited.

Table 1 The distribution of cisterns visited

Villages	Number of households visited	Number of people interviewed per household
Kibumba	4	2
Kibati	4	2
Buhuma	4	2
Bushwaga	4	2
Muja	4	2
Mutaho	4	2
Byahi	4	2
Munigi	4	2
Ngangi	4	2
Bujovu	4	2
Mujoga	4	2
Kiguri	4	2
Kabuye	4	2
Karungu	4	2
Kabindi	4	2
Buhimba	4	2
Kibiriga	4	2
Kisheke	4	2
Karungu	4	2
Bushara	4	2
Kanyaruchinya	4	2
Kanyanza	4	2
Mukondo	4	2
Karungu	4	2
Rusayo	4	2
Total	100	200

3.2. Characterization of cistern systems

In view of the traditional habitat types and the non-urbanized area, cisterns are traditionally designed and sometimes covered. The roof of the house serves as a catchment area, connected to a system of sheet-metal gutters that collect rainwater. At the end of this gutter system is a pipe, also made of sheet metal, which drains the rainwater to a cylindrical storage tank built of sheet metal and/or tarpaulin.

3.3. Tank hygiene

During the survey we found that 75% of tanks are not covered. 25% are covered, but unfortunately not properly. Some are covered with rusty sheet metal, while others are covered with worn and rotting rubber and bags. Uncovered and poorly-covered tanks are exposed to an environment where open defecation is commonplace, and the wind often stirs up dust. Cisterns are cleaned once a year by individuals who exhaust their stocks before the new rainy season, while in other cases cleaning is carried out at random after a long period (three years at least). Despite these collection conditions, rainwater is not treated, either after storage in cisterns or before use. It is therefore exposed to microbial contamination, presenting a health risk for users.

3.4. Use of cistern water

The unavailability of drinking water resources in Nyiragongo territory and the lack of financial resources force the population to use cistern water to satisfy their needs. Figure 2 shows the proportions of the various uses.

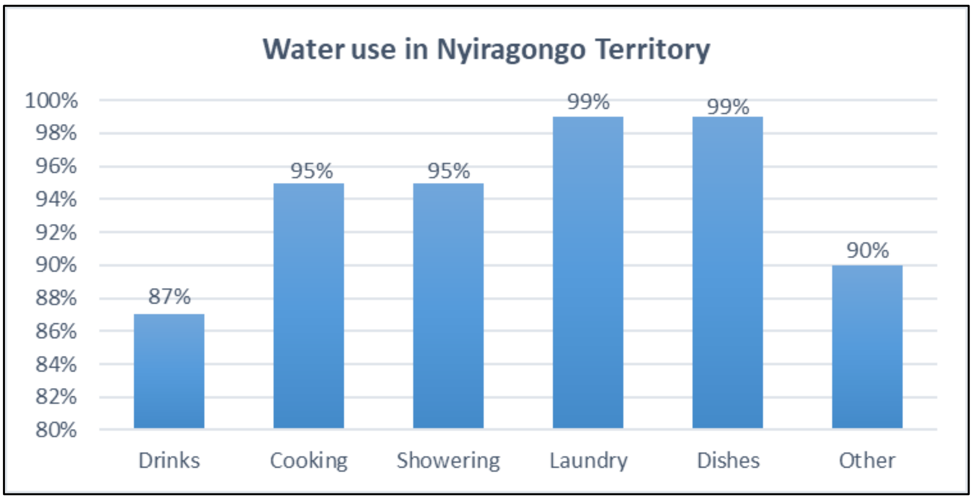

Figure 2 Water uses in Nyiragongo territory (in percent)

Figure 2 clearly shows that rainwater stored in cisterns is consumed more by the population of Nyiragongo in daily use, as they have no standpipes or natural or artificial sources such as wells. During the dry season, a few aid workers supply this population with water from tanker trucks, but this represents a negligible percentage of needs (barely 10%). Recurrent illnesses among the respondents are malaria, cholera, typhoid fever, skin diseases and tooth decay. (Figure 3). These diseases are water-borne and are thought to be due to the lack of hygiene in the cisterns. Indeed, uncovered cisterns are a habitat for mosquitoes, whose bites cause malaria. Other diseases, such as dermatological ailments and tooth decay, are linked to water quality.

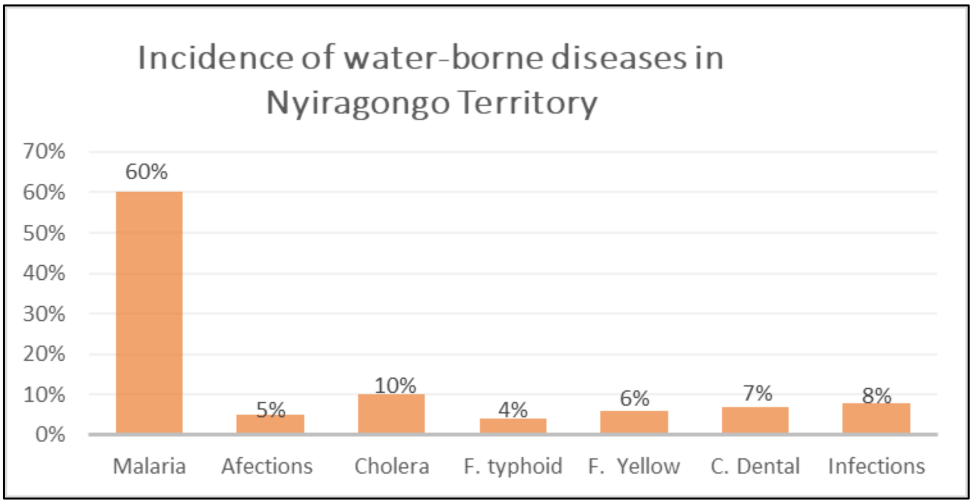

Figure 3 Frequency of water-borne and water-related diseases in Nyiragongo territory (in %)

3.5. Physico-chemical analysis results

To characterize the physic-chemical properties of the water stored in the tanks, we measured turbidity and ph. After analysis, the results show that neither turbidity nor pH meet the standards required by the WHO and the Democratic Republic of Congo. Figure 4 shows the variation in pH values measured for each tank numbered from 1 to 25.

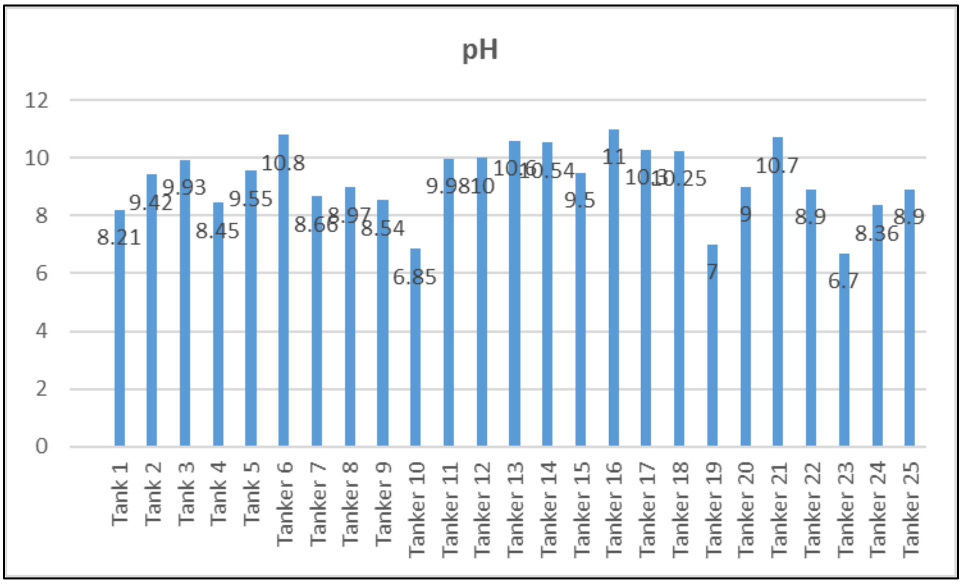

Figure 4 pH of water in sampled cisterns

The pH of the various samples of water stored in the tanks measured ranged from a minimum of 6.85 to a maximum of 11.0. Based on WHO and Democratic Republic of Congo values (6.5 and 8.5), we can see that 76% of these values are outside the norm, and only 24% are within it. The rise in pH (basic) values is thought to be due to exposure of the tanks to various types of particles from the atmosphere, notably the Nyiragongo and Nyamulagira volcanoes, which are close to the Nyiragongo territory and emit their gas plumes. The use of water with a high pH value could cause dermatitis [Dovonou, 2012].

With regard to turbidity, which characterizes water in terms of suspended solids, the maximum value tolerated by the WHO is 5 NTU (Figure 5). The 25 values of the analysis show turbidity ranging from 5.6 to 7.8 NTU. These data show that cistern water in Nyiragongo territory contains sufficient suspended solids. It could therefore be considered a source of water-borne diseases, and should be treated before consumption.

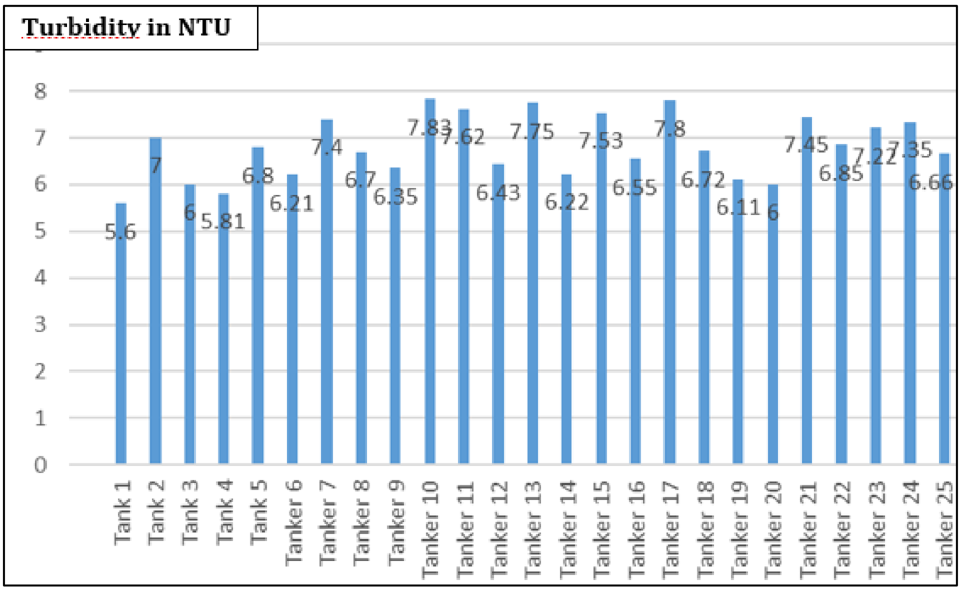

Figure 5 Variation in turbidity at different sites

3.6. Bacteriological quality of tank water

Testing for faecal contamination parameters is the general application for pathogen detection in water. This research was carried out in the ISTM BUKAVU laboratory. The results showed that none of the cisterns complied with WHO or Democratic Republic of Congo standards, so all were contaminated with bacteriological germs.

Common germs: 99.95% of the tank water sampled was contaminated with common germs (50 to 7776 CFU/ml). These results are shown in figure 6. These rates testify to the favourable conditions for germ development.

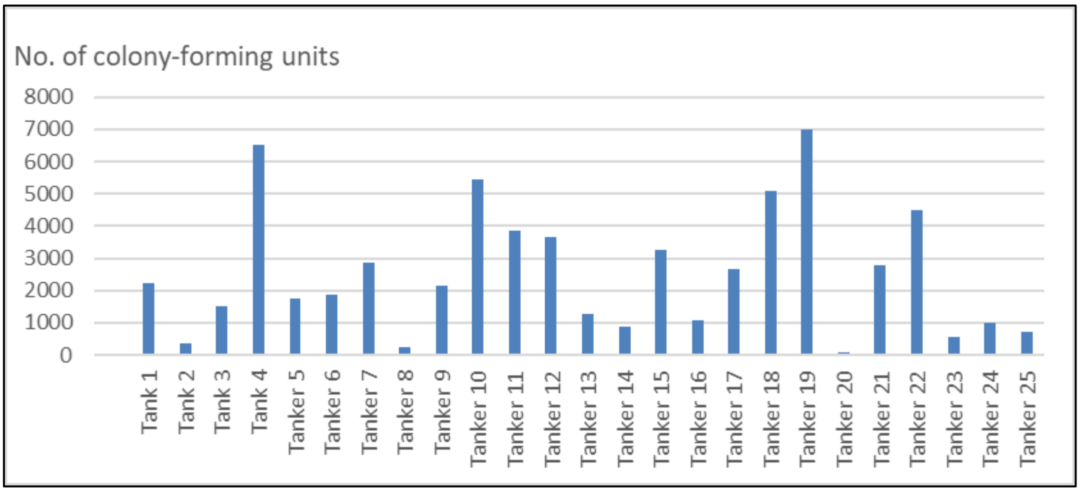

Figure 6 Common germs in tank water

- **Faecal coliforms and E. Coli**: 85% of water samples contained Escherichia coli (0 to 2750 CFU/100 ml) and 95% fecal coliforms (0 to 4290 CFU/100 ml). The presence of fecal coliforms and E. Coli confirms that these waters are polluted by fecal matter.

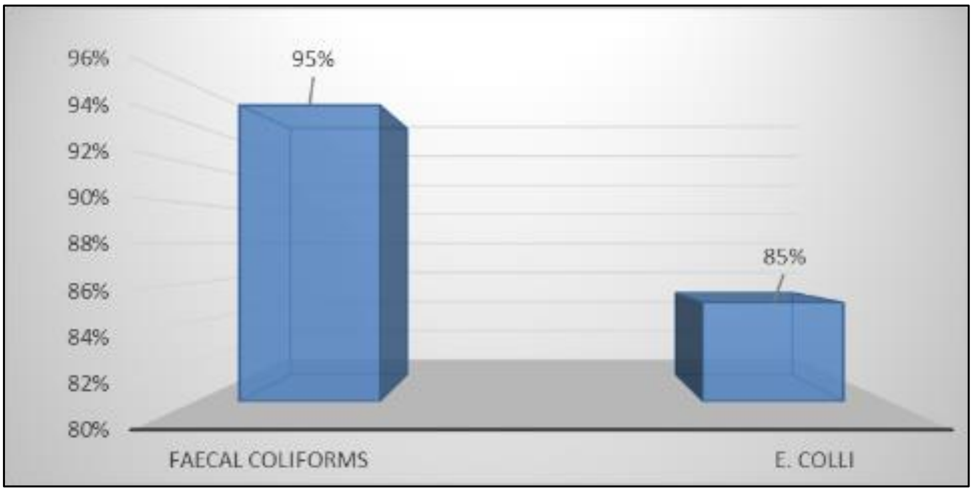

Figure7 Percentage of faecal coliforms and E. Coli in tank water

Assessment of the bacteriological quality of these waters according to Congolese [REGIDESO, 2015] and WHO standards reveals that the vast majority of water samples are of poor quality. On that note, the tank water analyzed can only be consumed after a severe chlorine treatment and also before any use in order to allow the elimination of these germs and to confer to the water a remanent protection due to the presence of residual chlorine contained in the water.

4. Discussion

The aim of this research was to study some of the characteristics of rainwater stored in cisterns in the Nyiragongo territory, in order to assess some of the consequences of its use. In this territory, the use of rainwater seems to be a constraint that compensates for the lack of drinking water supply points. According to surveys and analysis results, this water is not of good quality, and must undergo rigorous treatment by chlorination and zonation before being used by the population. This observation was also made by Bessedik M., (2015). According to Manizan et al, (2010) many factors contribute to the degradation of rainwater quality. During our survey, we found that none of the cisterns surveyed had a filtration device at the end of the funnel. Similarly, the majority of cisterns are not covered. This situation could be a potential source of microbial contamination and even chemical pollution, as is the case with the plume of gases from the Nyiragongo and Nyamulagira volcanoes, which create acid rain that falls in this area. The contamination of these waters is therefore due to several parameters. The pH of the water is basic, ranging from 6.85 to 11.0.

These results are similar to those obtained by Bengaibona (2010) in Burkina Faso, who found a basic pH of 8.9 to 10.6, and slightly higher than those of Manizan et al. (2010) in Belgium, whose well water had an average pH value of 7.4. It should be pointed out that basic pH water has no direct effect on health, but will tend to reduce disinfection efficiency, since a basic pH has a direct influence on the dose of chlorine to be applied, which will have to be higher (in basic pH). Water with a pH value above 9 can still cause eye irritation and aggravate skin conditions. According to the WHO (2016), although almost all faecal coliforms and common germs are non-pathogenic, drinking water must scrupulously comply with the following values: common germs 50 CFU/ml, thermotolerant coliforms 0 CFU/100ml, Escherichia coli 0 CFU/100ml, as faecal coliforms are indicators of faecal contamination. Indeed, the interest in detecting these coliforms lies in the fact that they are almost everywhere in nature. Escherichia coli, one of these coliforms, is the best indicator of fecal contamination. Analysis of this study shows that 99.95% of the waters are characterized by high total flora and 95% by fecal coliforms. These high fecal coliform values are far higher than those of Bengaibona (2010) (61%) and Manizan et al. (2010) (28.5%). This shows that contamination also depends on the living environment of users, maintenance and could be of three origins. These are atmospheric, telluric and faecal contamination. Atmospheric contamination is due to the fact that rainwater passes through the atmosphere, carrying with it the microorganisms it contains. Land-based contamination is due to soil dust containing germs carried by the air over the roof, washed off by rainwater or directly into the cistern due to the lack of a cistern cover or funnel filter. Lastly, contamination may be faecal, due to faecal germs from open-air defecation carried in the dust by the wind. The presence of Escherichia coli in the majority of samples confirms that contamination is largely of faecal origin, and may be at the root of some of the illnesses observed among users, such as cholera, infections and dermatological disorders, especially as users do not treat their water before using it. Several studies have shown that drinking water is polluted by microorganisms.

Work carried out by Djuikom et al (2009); Mbawala et al, (2010); Adandedji (2005); Hounsinou et al.., (2015) respectively in Douala (Cameroon), Ngaoundéré (Cameroon), Martil (Morocco); Lomé (Togo); Abomeycalavi (Benin) demonstrated fecal contamination by the presence of total Coliforms, thermotolerant Coliforms, fecal Enterococci and Clostridium perfringens in well water.

Total flora has also been counted by Adandédjan (2005). These waters also contain numerous pathogenic germs, including bacteria such as Salmonella sp, Vibrio parahaemolyticus, Pseudomonas aeruginosa (Mbawala et al., 2010); Shigella spp, Staphylococcus aureus and Candida albicans; Proteus penneri, Stenotrophomonas maltophilia , Citrobacter freundii.

Well water has a more defective microbial quality than borehole water. Dovonou, (2012 and Adandedji (2005) found a significant difference between well water from different localities. As cistern water is mobilized by man, it is more vulnerable to the various risks of contamination if hygiene measures are not taken.

5. Conclusion

The above results show that rainwater collected from roofs is subject to microbial contamination and could contain pathogenic germs. But it can be treated with chlorination in every household and used as drinking water, since it is not contaminated. Many precautions should also be taken to ensure the potabilization of these waters, since cistern water remains a real alternative and permanent source of water consumption, despite the scarcity of functional drinking water supplies in the Nyiragongo Territory.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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