Original Research Article

Water source management in the peri-urban area in Subsaharan Africa: Environmental and health impacts assessment in Yaounde-Cameroon

ABSTRACT

This study examinedThe study carried out in the outskirts of the Yaoundé VII district had the main objective of assessing the social and environmental impacts of water management in the outskirts of Yaoundé VII. This work was carried out from December 2021 to March 2022, followed by an appropriate methodology to meet the outlined objectives.

(1) in-situ evaluation of physicochemical parameters of well water; (2) laboratory studies of groundwater samples for bacteria and heavy metals; and (3) questionnaire surveys to acquire water consumption demographics were all part of our study.

It consisted of under taking site visits, take pictures, make household surveys and direct observations, analysis at several water points.

The results show that the villages in the surrounding area of the district of Yaoundé VII obtain water through alternative resources such as wells at 60 %, sources 30 %, drillings, 7 %, rivers and others at 3 %, due to lack of Camwater network. Analysis at the water points has revealed that the physic-chemical parameters such as COD, BOD5, TSS, NO3, PO3, have average percentages respectively 83 mg/L, 35 mg/L, 14 mg/L, 0,33 mg/l And the biological parameters such as fecal coliforms fecal streptococci and total coliforms have percentages of 329,25 (UFC/100 ml), 115,5(UFC/100 ml), 835 (UFC/100 ml), These parameters in their majority do not meet with the MINEPDED environmental standards. This can be explained due to anthropogenic activities (fields, brick, factories ,etc), that impact on the quality of water from different points of water villages covered however, 10 positive and 02 negative impacts were identified. Among the negative impacts, it has been noted….whist the positive impacts were….Alternative water resources in the villages do not meet certain environmental standards and human anthropogenic activities are a source of negative impacts such as poor well maintenance, which can cause many water borne diseases like typhoid fever.

UNDER PEER REVIEW

More supply in water like boreholes should be built, or establish the Camwater network for better water management by the populations of the peripheral zone of the district of Yaoundé VII.

Key words: Impacts, water resources, Water supply, Yaoundé VII, Management.

UNDER PEER REVIEW

1. Introduction

Water is a worldwide public good and a common heritage of mankind; it fulfils a multitude of functions(Aboagye & Zume, 2019). Living organisms could hardly do without it, in the sense that it determines their livelihood, well-being and productivity. Access to safe water and good sanitation have long been issues in a lot of countries around the World(Aboagye & Zume, 2019). All this supports the assertion that "water is essential for life" (Duhamel & Brouard, 2010). Thus, according to some estimation, more than one billion people worldwide do not have access to safe water sources (Jury & Vaux, 2005).

Most developing-country households' drinking water is unsafe(Abu Amr & Yassin, 2008).Some African cities do not have piped water, so inhabitants rely on alternative low-quality water sources such as rivers, springs or groundwater. The supply of safe drinking water is becoming a growing problem for the community, particularly in light of the changing climate-depleted biodiversity. With rising demand, access to clean drinking water for residential consumption has become a key concern for modern communities (Yongsi, 2010).

In Africa, the problem is not the lack of water resources, but rather the infrastructure to access them. Indeed, out of 5400 million cubic metres of renewable water per year in Africa, only 4% is used for drinking, irrigation and energy(Olasoji et al., 2019). Cameroon in particular, which is a Central African country, is not on the verge of this situation, although it has generally favourable natural conditions and abundant water resources everywhere, which is why it is considered the second most water-rich country in Africa after the Democratic Republic of Congo (Ananga Rose Pulcherie et al., 2019). Even though it is the responsibility of the State to develop the right to water and to make it tangible, it must be noted that despite the strong potential of our country, there is a contrast with the difficult access to drinking water that the populations of the country.

As such water, commonly known as 'blue gold', is an increasingly scarce commodity and therefore increasingly expensive(Meride & Ayenew, 2016; Tabué Youmbi et al., 2011). Just like other Cameroonian cities, Yaoundé, which is the political capital of the country, is subject to many stress factors, amongst which are the problems of drinking water supply, as the expansion of the drinking water network does not always keep pace with the population(Akaho et al., 2022). Less than 60,000 households have access to a drinking water supply network for a population estimated at more than two million inhabitants, yet access to quality drinking water was recognised by the UN on 20 July 2010 as a fundamental human right. This declaration calls upon all governments to provide safe, clean, accessible and affordable drinking water for all. In order to provide solutions to this critical situation of lack of drinking water, the government has implemented an action plan from 2008 to 2015 with the aim of achieving an access rate of 80% of drinking water. He launched a reform of the urban and peri-urban water sector that focused on rehabilitation, renewal, reinforcement and extension of the production and distribution capacity of existing centres, as well as the construction of new drinking water plants in many towns that lacked them(Nganti, 2012).

Nowadays, in spite of all these state enterprises, access to drinking water in the city of Yaoundé is a luxury, as the current production of drinking water from the Akomnyada plant (100,000 m^3/day) and the Mefou plant (50,000 m^3/day) is far below the demand, which is around 300,000 m^3/ (Estella et al., 2016; WAGNER & LANOIX, 2020). This unfortunate situation compels the population to seek solutions on their own by appealing to alternative sources such as surface and underground waters, each one using its own strategy according to the means at its disposal, the low cost of setting up compared to that of the CDE (Cameroon Water Company) connection, and their high level of productivity at the household level, surface aquifers on crystalline bedrock are the privileged sites for the installation of wells and are therefore much in demand(Nganti, 2012).

Because of the diversity of these environments and their inhabitants, long-term management evaluation methodologies for aquatic ecosystems should be permanent. As a result, the necessary tools should be made available to institutions and decision-makers in order to better understand and manage these complex and dynamic ecosystems throughout time. Physicochemical or biological characteristics are commonly employed to assess the

UNDER PEER REVIEW

health of water resources. Several studies in Cameroon have focused on, assessment of pollutionand ecological risk of heavy metals in urban water sources, AssociatedHealth Risks linked to Drinking-water, Assessment of the Physico-chemical andBiological Water Quality in a Sub-urban Area in urban, peri-urbanareas (Aboubakar et al., 2021; Akaho et al., 2022; Ananga Rose Pulcherie et al., 2019; Foto Menbohan et al., 2013; Ghoutum et al., 2020; Lebga et al., 2019; Nzouebet et al., 2019; Pierre Chegaing Fodouop et al., 2021; Yongsi, 2010). The present work is therefore part of the ongoing efforts applied to the geo-specific physico-chemical Water Quality assessment peri-urban area in Cameroon.The main objective of this study was to evaluate the social and environmental impacts of water resource management in the outlying areas of Yaoundé VII. In more specific terms, Carry out an overview of the various water resources and their management in the Yaoundé peri-urban area and investigate physio-chemical characteristics of household 'use water of the study area.

2. Materials and Methods

2.1 Study Area

Cameroon is a Sub-Saharan African country located at the bottom of the Gulf of Guinea, between 2 and 13 ° latitude north and 8 and 16 ° longitude east. Nigeria, Chad, Central African Republic, Congo, Gabon, and Equatorial Guinea are its neighbours. Cameroon is the most populated nation in Central Africa, with a population of 23,739,218 people(Bot et al., 2022).Yaounde is Cameroon's political capital, lying between longitudes 11.412 and 11.576 East of the Greenwich meridian and latitudes 3.715 and 3.963 North of the equator. More over half (51%) of the capital is made up of slums with no piped water supply and no centralised sanitation and waste disposal facilities. For drinking water, the people must rely mostly on shallow drilled wells and springs(Lebga et al., 2019). Yaounde has a characteristic Guinea equatorial climate with four seasons: long dry season (November to March), long rainy season (March to June), short dry season (July to August), and short rainy season (September to November), with an annual rainfall of roughly 1700mm. The temperature ranges from 23° to 25° C (Ghoutum et al., 2020).

UNDER PEER REVIEW

2.2 Overview **of alternative water sources and their management in the studied area**

2.1 Overview

Data were collected during field visits between 1st January and 28th February 2022 in the following neighbourhoods of the peripheral zone : Ebot-Mefou, Akok-Ndoe II,Moinkoa-Meyos and Nkol-Nkoumou.

The field surveys were carried out individually using questionnaires and interview sheets drawn up beforehand. We interviewed The mayor of the Yaoundé VII district was interviewed. The sub-prefect, the various chiefs of the villages we visited, and officials from the Ministry of Water and Energy were also interviewed.

We also conducted surveys in various households in the different villages in order to gather all the important information needed to carry out this work.

The field observations enabled us to enhance the surveys and interviews carried out, to see the different water resources used by the inhabitants of our study area, to know how these populations use them and also to see the different social and economic activities carried out by them.

2.2 determination ofphysico-chemical and bacteriological parameters of the sampled water sources

The choice of the selected water points was made after analysing the survey forms andobservations made in the field, such as: thegeographical location, the number of existing latrines within a 15 m radius of the structure and other polluting points, the layout of the water point, the rate of use by the inhabitants and accessibility. Water samples were collected in bottles initially sterilised in the laboratory and rinsed three times with sample water at the site before collection. Well water was collected using containers commonly used by residents before being transferred to the bottles for sampling. For spring and borehole water, samples were taken directly from the sampling bottles. The water samples taken were directly stored in

UNDER PEER REVIEW

a cooler containing carbohydrate ice from the sampling site to the Biotechnology and Environment Laboratory of the University of Yaoundé I for analysis. The analysis was carried out at the Laboratory of Biotechnology and Environment, of the Department of Plant Biology and Physiology in the University of Yaoundé I. Seven water samples were taken from 3 wells, 1 borehole and 3 springs respectively. Physico-chemical parameters such as temperature, pH, conductivity (µs/cm), suspended solids (SS in mg/l), nitrates NO^{-}_{3}(mg/l), ammonium ions NH_4^+ (mg/l), and chloride ions were determined according to Standard Methods for the Examination of Water and Wastewater (Baird et al., 2017).

- **Temperature**

It was measured using a multimeter of the brand HQ14d. It is fitted with a standard probe that was dipped vertically into the water sample taken from a 500 ml jug. The value is read directly on a digital display screen by selecting the corresponding button; the results are expressed in °C.

- **pH**

The pH was determined using a Hach pH meter (HQ11d). After pre-calibration of the pH meter with the value buffers 7.00 and 4.01, the glass electrode was inserted into a decanter containing 100 ml of sample and the values were read on the digital display.

- **Conductivity**

The electrical conductivity was measured using a Hach conductivity meter (HQ14d). This instrument is fitted with a standard probe that is immersed vertically in the solution whose concentration is to be determined. The conductivity value is read off on a digital display. This conductivity is expressed in µS/cm or mS/cm depending on the concentration of the sample.

- **Total Suspended Solids (TSS)**

It is obtained by direct reading on the Hach DR/3900 spectrophotometer. It measures the optical property of a water sample, which is achieved by the dispersion and absorption of light beams by the particles present. The determination of TSS is done by the so-called "absorptometric" method. The value of each sample is read directly on the Hach DR/3900 spectrophotometer at 810 nm. The control is distilled water (Maiga, 2015).

- **Ammonium ions**

Ammonium ions were determined by the Nessler reagent colorimetric method using a Hach DR/3900 spectrophotometer. After distillation with 40% soda in a Buchi K-350 distiller,

UNDER PEER REVIEW

25 ml of the distillate collected in a boric acid buffer were taken and placed in a spectrophotometric cell, to which were successively added 3 drops of mineral stabiliser and polyvinyl alcohol and then 1 ml of Nessler reagent. The coloration of the complex due to the presence of NH4+ ions is read with a DR/3900 spectrophotometer at 425 nm. The content of the parameter considered is read on the digital display screen of the apparatus with reference to a control consisting of distilled water. The results are expressed in mg/l of NH4+.

- **Nitrates**

Nitrate ions were determined by the cadmium reduction method using a Hach DR/3900 spectrophotometer. After introducing 10 ml of sample into a spectrophotometric cell, a packet of Nitraver 5 was added. The mixture is then homogenised and left to stand for 5 minutes (reaction time). The coloration developed in the presence of NO3- is then read with a spectrophotometer at 500 nm. The content of the parameter in question is read on the digital display screen of the apparatus by reference to a control consisting of 25 ml of the sample. The result is expressed in mg/l.

- **Chlorides**

The principle of this method is based on the reaction of chloride in the sample with mercuric thiocyanate to form mercuric chloride and release the thiocyanate ion. The thiocyanate ions react with ferric ions to form an orange ferric thiocyanate complex. The concentration of this complex is proportional to the concentration of chloride. After introducing 25 ml of sample into a cell, 2 ml of mercury thiocyanate and 1 ml of ferric solution were added. The mixture was homogenised and left to stand for 2 minutes (reaction time). The reading was taken at 455 nm with a Hach DR/3900 spectrophotometer and the result expressed in mg/L.

- **Chemical Oxygen Demand (COD)**

The measurement of the chemical oxygen demand is done by the so-called "reactor digestion" method. After homogenisation of the wastewater samples, 2 ml are taken and introduced into COD tubes, then incubated in the presence of a control at 150 °C for 2 hours in a Hach COD reactor (multi-tube heater). After cooling the tubes, the COD value of the sample is read in mg/l, using a Hach DR/2010 spectrophotometer, at a wavelength of 600 nm (Nganti ,2012).

- **Biochemical Oxygen Demand (BOD_5) in 5 days**

UNDER PEER REVIEW

The determination of the biochemical oxygen demand was done by the so-called "manometric" method using a Hach BOD5 apparatus (model 2173B). BOD5 bottles containing 164 ml of wastewater for the inlet and 250 ml for the sampling tube and outlet, to which a BOD5 nutrient buffer is added, are incubated for 5 consecutive days at a temperature of 20 °C. During this period, the bacteria use the oxygen in the upper part of the bottle to oxidise the organic matter in the solution and release CO2. The CO2 is fixed by the potassium hydroxide crystals (present in the cup placed at the top of each bottle called Oxitop). The BOD5 value is read directly on the Oxitop (Renaud, 2012).

The determination of faecal coliforms and faecal streptococci was done by the membrane filtration method described by (Rodier, 2009). The samples were filtered onto a 0.45µm membrane using a vacuum pump under sterile conditions. After filtration, the membrane was placed in a petri dish containing the appropriate culture medium. The culture media for faecal streptococci (FS) consists of Bile Esculin Azide agar (BEA) while for faecal coliforms (FC) it is Tetraphenyl Tetrazolium Chloride (TTC) and tergitol 7 medium. The latter are then placed in incubators at 35° C for SF and 44.5° C for CF for 24 hours. After incubation, the colonies were counted and their total number estimated by the formula :

$$\mathrm{UFC} = \frac{\text{Nombre de colonies comptées}}{\text{Volume d'échantill on filtré (ml)}} \times 100\ \mathrm{ml}$$

3. Results

3.1 Current status of water sources

According to this survey, the inhabitants of the peri-urban area of the Yaoundé VII district use several methods of water supply, namely: boreholes, wells, springs and streams (Fig. 1). Wells are used by 60%, springs by 30%, and boreholes and streams (rivers and swamps) by 10%.

UNDER PEER REVIEW

Fig.1. Water resources exploited by the populations in the study area (a-Drilling; b-Source; c-Wells; d-River).

According to the field surveys, for practical reasons, jerry cans (65%), bottles (25%), and buckets are the main means of storing the water collected and to a lesser extent we also have tanks, barrels and others (10%) (Fig.2)

The conservation period varies between households and ranges from 24 hours to more than a week. The water is still consumed within one to five days after it has been collected.

UNDER PEER REVIEW

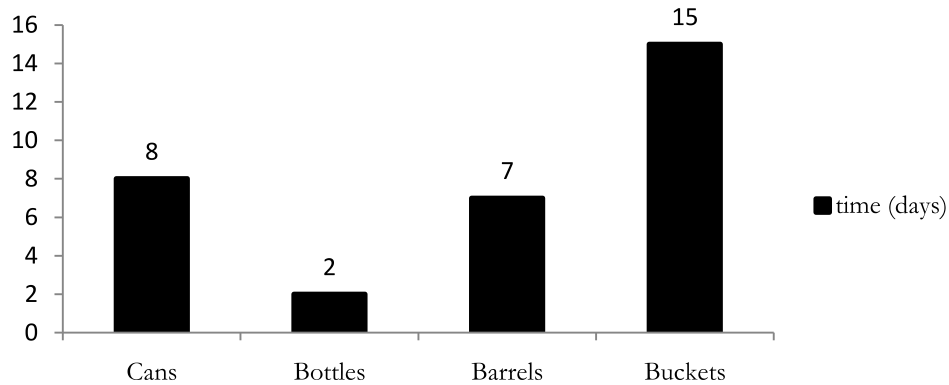

Fig.2. Conservation period of water in households.

The populations of the peri-urban area of the Yaoundé VII district do not use the collected water for the same purpose. Some use it for drinking, others for cooking, others for bathing and other for domestic chores. (Fig.3).

The surveys revealed that of these water resources, 80% are used for domestic purposes.

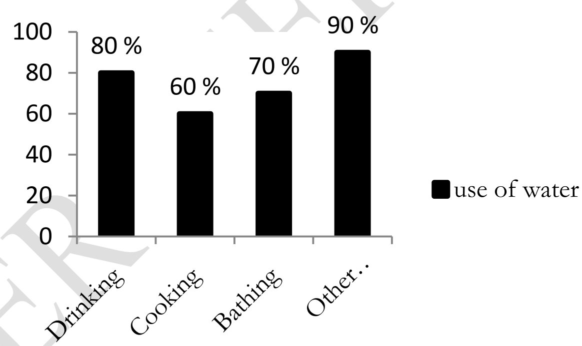

Fig.3. Different uses of water by the population.

UNDER PEER REVIEW

3.2 Characterisation of water used by people in the studied area

The measured colour from the different sampling points shows a value of 307 PtCo at P1, 54 PtCo at P2, 182 PtCo at P3 and 39 PtCo at P4. The statistical analysis of this parameter shows a difference between the withdrawals of different water supply points in the four villages (Fig.4).

Table I. Physico-chemical parameters of supply points (Continued).

Parameters / Sampling points	MES (mg/L)	Fe+2	COD (mg/L)	BOD5 (mg/L)
Well (P1)	33	1.473	83	35
Borehole (P2)	6	1.822		
Sources (P3)	13	0.22		
River (P4)	4	0.428		
WHO standards	0.5		500-1500	

Fig.4. water colour (a-water colour at river level; b-water colour from a spring).

The average concentrations of groundwater recorded were 26.9°C (T), 48.3 (W), 66.32 mg/L (STD), 5.82 (pH), 126.3µS/cm (CND), 10.47 mg/L (Cl-), 26.55 mg/L (NO3-), 4.3 mg/L (TSS), 0.047 mg/L (NH4+), 393 CFU/100mL (CF), 26.7 CFU/100mL (SF). It appears from the laboratory analyses that certain parameters do not comply with the standards, such as the bacteriological ones obtained, which reveal the presence of faecal streptococci and total and faecal coliforms. The results of these analyses are summarised in Table I above.

The analysis of the groundwater reveals the presence of high concentrations of faecal coliforms in the water from wells, springs and boreholes, as shown in Table II. It can be seen

UNDER PEER REVIEW

that none of the water points sampled have a good bacteriological quality (coliform concentration 0 CFU/100ml of water). The concentrations are well above the recommended potability threshold; in fact, microbiological criteria require that faecal coliform concentrations in drinking water must be of 0 CFU/100ml.

The results of bacteriological analysis revealed the presence of high concentrations of faecal streptococci in well and spring water (Table II.).

The average value of 115.5 CFU/100 ml exceeds the WHO standards, which require the concentration of faecal streptococci in drinking water to be 0 CFU/100 ml.

On the basis of these bacteriological results, we note that all the water taken from wells, springs, boreholes and rivers is polluted by faecal coliforms and faecal streptococci. All this suggests that all the water at our various points has been contaminated.

Table II: Bacteriological parameters of supply points.

Water sources / Parameters	Point 1	Point 2	Point 3	Point 4
CF (UFC /100ml)	294	414	213	396
SF (UFC/100ml)	96	114	135	117
CT (UFC/100ml)	420	1656	644	620
Standards (according to WHO)	0 UFC/100 ml	0 UFC/100 ml	0 UFC/100 ml	0 UFC/100 ml

The Nkolbisson Health District records data on diseases from the various health centres in the Yaoundé VII district. After analysing these data, two main water-borne diseases were recorded over the last six months, with a greater exposure among adults (58.2%) than among children (41.8%). These are malaria, typhoid fever and amoebiasis with respective percentages of 50.50%, 40.62%, and 8.82% (Fig.5).

UNDER PEER REVIEW

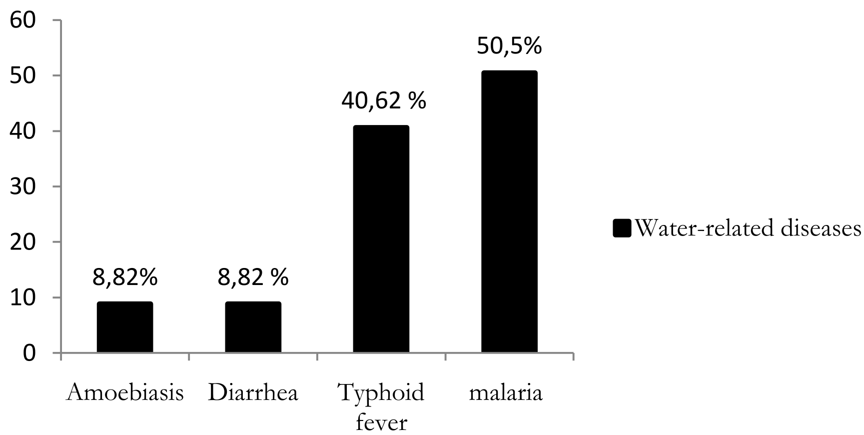

Fig.5. Epidemiological diseases in the study area.

The surveys revealed that 67.5% of households had suffered from a disease, with children (58.73%) being more exposed than adults (41.27%) in the six months preceding the study. These were waterborne diseases (Fig.6) Amoebiasis (29.85%), diarrhoea (34.33%), typhoid fever (34.33%), and malaria (50.37%).

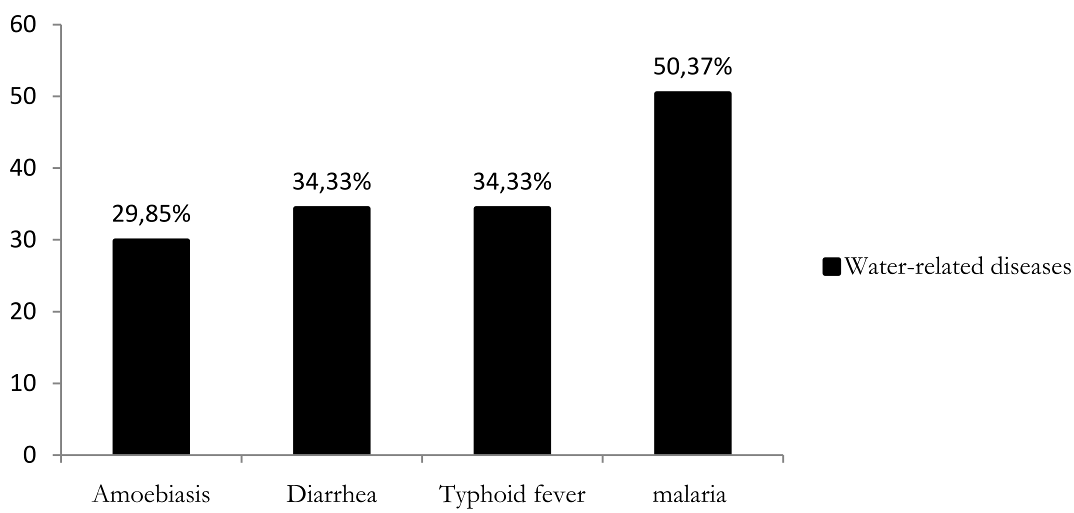

Fig.6. Different water-related diseases, identified in the villages visited.

4. Discussion

Water sources are classified into three types(Alia et al., 2018): Groundwater, surface water, and rainwater. These enables the population to satisfy its needs to the best of its ability.

The most commonly used water sources are 60% wells, 30% springs, and 10% boreholes and others in the study area. This corresponds with the studies carried out by Armel, 2013.

The ways in which these water sources are used vary according to whether they are used for cooking, drinking, domestic work or other purposes. In general, the anthropogenic activities that contribute to the pollution of these sources are agricultural practices with the use of fertilisers and pesticides near water sources (25%), the construction of latrines near wells and poor maintenance of these wells (55%), and other activities (20%).

The results of the analysis of the storage methods used by households showed that jerry cans were used more for storing water (36.07%). This preference can be explained by the advantages of this method of storage. Cans have a larger capacity than bottles, which offer the same level of protection. In addition, they are easier to transport than buckets, which can fall over during transport, and drums/tankers, which are very heavy to transport. However, these results are contrary to those of Nana (2013) who, working on access to drinking water and the risk of diarrhoea in irregular areas of Ouagadougou, noted a low use of jerry cans (2.38%) in Yamtenga, in contrast to the earthen jar (83.33%). According to this author, this high percentage can be explained by the ignorance of the population in this area about the dangers of this method of water conservation.

According to the analysis, households keep their drinking water for 2 to 3 days and up to a week. However, the storage period for drinking water should not exceed 24 hours. Therefore, this prolonged storage period of drinking water would constitute an important factor in the degradation of its quality(Boti et al., 2019). Indeed,(Ngnikam et al., 2007) working on water, sanitation

Impact on health: a case study of an urban ecosystem in Yaoundé, observed that after three days of storage, more than 80% of the water samples analysed were of poor quality.

The pH of the water analysed is between 5 and 5.91. These pH values reveal the acidic nature of the groundwater in Yaoundé, an acidity that could be linked to the nature of the

UNDER PEER REVIEW

parent rock. Indeed, geological and pedological studies of Yaounde have shown that its site is located on a magmatic base complex of Precambrian age: an acidic soil where iron is included in black micas and garnets. These results are similar to those obtained by (LIEGUI, 2018), Nana (2013) who both worked on the characteristics of the groundwater of the city of Yaoundé and observed that it had an acidic character.

The presence of chemical elements such as nitrates in groundwater could have not only a natural origin (degradation of the bedrock) but also an anthropogenic origin (diffuse pollution due to leaching from rubbish dumps and/or latrines). To this effect, (Maiga, 2005) working on geochemistry and groundwater pollution showed that the presence of nitrates in water could be due to diffuse pollution caused by seepage processes of wastewater, leaching from rubbish dumps and excreta on the one hand but also to incomplete degradation processes of organic matter. The low nitrate content in the water is due to the fact that, apart from latrines and some dumps, other sources of pollution such as livestock farms and agricultural holdings are also present in the study area. The nitrate concentration in the well is lower than the 50 mg/l recommended by the WHO and could be due to the topographical position of the well. Indeed, being located in the lowlands, it receives wastewater from pipes located less than 5 m from it. In addition, some wells are poorly designed. Furthermore, not far from some of the wells, there are rubbish dumps that communicate directly with the water body.

The germs responsible for faecal pollution were found in 90% of the water analysed. A large part of this pollution can be attributed to the existence of latrines located near certain water points. But also to the sanitation practices of the area. Indeed, more than 90% of the households in the study area discharge their wastewater into the environment. In addition, people and animals defecate in the open air. All this contributes to the microbiological contamination of the water table through the process of diffusion of contaminants in the soil. Moreover, some of these points (wells and springs) do not respect the protection standards. In fact, most of them are open or half-closed by a sheet of metal and the wells are abandoned on the ground. Similar observations were made by(Coulibaly, 2005). This author, working on the physico-chemical and bacteriological quality of well water in certain neighbourhoods of the District of Bamako, showed that faecal contamination of groundwater was linked to the proximity of latrines to water points and also to the lack of protection of these sources.

UNDER PEER REVIEW

Several cases of disease were recorded during the household surveys: no cases of cholera, 28 cases of diarrhoea, 20 cases of amoebiasis, 29 cases of typhoid fever and 68 cases of malaria. These results would be the result of the consumption of poor quality water. This quality could be influenced by the fact that the water was kept for more than 24 hours, and by the poor management of wastewater and excreta. Most wastewater ends up in the environment and is therefore likely to degrade groundwater. In addition, open defecation was observed among some respondents. Indeed, the work of(Ngnikam et al., 2007), working on water, sanitation and health, has shown that degradation of water quality combined with poor sanitation would be associated with health risks for populations. In addition, these diseases could also be explained by poor hygiene. Indeed, only 23.95% and 18.85% of households wash their hands after leaving the toilet and before meals respectively.

Bacteriological analysis of the water revealed that borehole water is less polluted than well and spring water. However, the household survey showed that households using borehole water are the most exposed to waterborne diseases. This inconsistency in the results could be explained by the fact that borehole water is used more for drinking than well and spring water, which is used for household chores. Furthermore, waterborne diseases are dependent on the quality of water consumed by households, which is itself influenced by practices such as storage time, type of containers and whether or not potabilisation techniques are applied before consumption.

5. Conclusion

This research was aimed at evaluating the environmental and social impacts of human activities on water sources in the peripheral zone of the Yaoundé VI district. It involved field visits to carry out surveys, direct observations and also some water sampling for physico-chemical and bacteriological analyses. It is clear from all this that households use several methods of water supply. Groundwater (wells, boreholes, springs) is used more than surface water (rivers, marigot). Many households (70%) store drinking water for several days beyond the recommended 24-hour storage time for water in buckets or barrels.The populations carry out several activities around these water sources which are potential sources of impacts on water management. In addition, factors such as poor wastewater management (more than 90%

UNDER PEER REVIEW

of households discharge their wastewater into the environment) and domestic waste could be sources of groundwater and surface water pollution. In addition, analysis carried out showed that the majority of water points sampled in the study area are contaminated by faecal matter with concentrations of up to 444 (UCF/100 ml) for faecal coliforms and 135 (UCF/100 ml) for faecal streptococci higher than the norms in place, by MINEPDED, hence all the water sampled is not of good quality. Poor water quality and poor sanitation practices expose households to water-related diseases such as malaria (50.50%), typhoid (40.62) and amoebiasis (8.82%).

UNDER PEER REVIEW

References

Aboagye, D., & Zume, J. T. (2019). Assessing groundwater quality in peri-urban localities of Kumasi, Ghana. *African Geographical Review*, *38*(4), 390–405. https://doi.org/10.1080/19376812.2018.1484781

Aboubakar, A., Douaik, A., Mewouo, Y. C. M., Madong, R. C. B. A., Dahchour, A., & El Hajjaji, S. (2021). Determination of background values and assessment of pollution and ecological risk of heavy metals in urban agricultural soils of Yaoundé, Cameroon. *Journal of Soils and Sediments*, *21*(3), 1437–1454. https://doi.org/10.1007/s11368-021-02876-4

Abu Amr, S. S., & Yassin, M. M. (2008). Microbial contamination of the drinking water distribution system and its impact on human health in Khan Yunis Governorate, Gaza Strip: Seven years of monitoring (2000-2006). *Public Health*, *122*(11), 1275–1283. https://doi.org/10.1016/j.puhe.2008.02.009

Akaho, A. A., Tikeri, G. B., & David, A. O. (2022). Physicochemical Analysis of Potable Water in Baham Community, Western Region of Cameroon. *Journal of Applied Sciences and Environmental Management*, *26*(7), 1203–1209. https://doi.org/10.4314/jasem.v26i7.3

Alia, A., Mekideche, M., & Benfridja, L. (Encadreur). (2018). *Etude physico-chimique et microbiologique des eaux de l'Oued Amsal (Ziama Mansouriah)*. http://dspace.univ-jijel.dz:8080/xmlui/handle/123456789/1862

Ananga Rose Pulcherie, N., Gideon Aghaindum, A., Abou Elnaga, Z., & Pierre, N. (2019).

An Ecological Assessment of the Physico-chemical and Biological Water Quality in a Sub-urban Area in Cameroon: Case of the Ngoumou Rural Council. *International Journal of Natural Resource Ecology and Management*, *4*(6), 198. https://doi.org/10.11648/j.ijnrem.20190406.16

Baird, R. B., Eaton, A. D., & Rice, E. W. (2017). 2540 Solids. In *Standard Methods for the Examination of Water and Wastewater*.

Bot, B. V., Gaston, J., Olivier, T., Sosso, T., & Pascal, M. (2022). Assessment of biomass briquette energy potential from agricultural residues in Cameroon. *Biomass Conversion and Biorefinery*, *0123456789*. https://doi.org/10.1007/s13399-022-02388-2

Boti, C. T. B., Kenfack, S., Gnagne, T., & Soro, G. (2019). Économie d'eau des toilettes, une approche crédible de réduction du déficit en eau potable de la ville d'Abidjan (Côte d'Ivoire). *International Journal of Biological and Chemical Sciences*, *13*(5), 91–104. https://doi.org/10.4314/ijbcs.v13i5.7S

Coulibaly, K. (2005). *Etude de la qualite physico-chimique et bacteriologique de l'eau des puits de certains quartiers du District de Bamako*. http://indexmedicus.afro.who.int/iah/fulltext/Thesis_Bamako/05P50.PDF

Duhamel, J. F., & Brouard, J. (2010). L'eau et l'hydratation : une nécessité pour la vie. *Journal de Pediatrie et de Puericulture*, *23*(1), 9–12. https://doi.org/10.1016/j.jpp.2009.12.002

Estella, N., Tamungang, B., Alakeh, N., Lum, M., Niba, F., & Jude, S. (2016). Physicochemical and bacteriological quality assessment of the Bambui community drinking water in the North West Region of Cameroon. *African Journal of Environmental Science and Technology*, *10*(6), 181–191. https://doi.org/10.4314/ajest.v10i6.

Foto Menbohan, S., Tchakontén, S., Adandedjan, G., Zebaze Togouet, S., Bilong Bilong, C., & Njiné, T. (2013). *WATER QUALITY ASSESSMENT USING BENTHIC MACROINVERTEBRATES IN A PERIURBAN STREAM (CAMEROON) Foto Menbohan S Ajeagah Gideon A Zebaze Togouet S . H Bilong Bilong C . F*. *2*(5), 91–104.

Ghoutum, A., Wiylahnyuy Edith, K., & Kohtem Lebga, A. (2020). Landfill Site Suitability Selection Using Geospatial Technology for the Yaounde Metropolitan City and its Environs: Case of Soa Subdivision, Cameroon. *European Scientific Journal ESJ*, *16*(6).

UNDER PEER REVIEW

https://doi.org/10.19044/esj.2020.v16n6p95

Jury, W. A., & Vaux, H. (2005). The role of science in solving the world's emerging water problems. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(44), 15715–15720. https://doi.org/10.1073/pnas.0506467102

Lebga, A. K., Ngo, N., Marie, N., Simone, L., & Yemmafouo, A. (2019). *Peri-urban dynamics: The case of Yaounde town and its environs*. *November 2018*. http://www.ijser.org

LIEGUI, G. S. (2018). Vermicompostage : Une Alternative Durable De Valorisation Des Déchets Organiques Ménagers En Maraîchage Périurbain À Yaoundé (Cameroun). *Liège Université Gembloux Agro-Bio-Tech*, *79,* page3. https://matheo.uliege.be/handle/2268.2/8344

Maiga, A. S. (2005). *Qualite organoleptique de l'eau de consommation produite et distribue par l'EDM.SA dans la ville de Bamako*. http://indexmedicus.afro.who.int/iah/fulltext/Thesis_Bamako/05P43.pdf

Meride, Y., & Ayenew, B. (2016). Drinking water quality assessment and its effects on residents health in Wondo genet campus, Ethiopia. *Environmental Systems Research*, *5*(1), 1–7. https://doi.org/10.1186/s40068-016-0053-6

Nganti, N. (2012). *Etude diagnostique de l'état de pollution des eaux souterraines de l'ilot de Nkolbikok--Yaoundé--Cameroun*. 2IE.

Ngnikam, E., Mougoue, B., & Tietche, F. (2007). Eau , Assainissement et impact sur la santé : étude de cas d ' un écosystème urbain à Yaoundé. *Actes Des JSIRAUF, Hanoi, 6-9 Novembre 2007, June*, 13.

Nzouebet, W. A. L., Kengne, E. S., Wafo, G. V. D., Wanda, C., Rechenburg, A., & Noumsi, I. M. K. (2019). Assessment of the faecal sludge management practices in households of a sub-Saharan Africa urban area and the health risks associated: the case study of Yaoundé, Cameroon. *International Journal of Biological and Chemical Sciences*, *13*(5), 1. https://doi.org/10.4314/ijbcs.v13i5.1s

Olasoji, S. O., Oyewole, N. O., Abiola, B., & Edokpayi, J. N. (2019). Water quality assessment of surface and groundwater sources using a water quality index method: A case study of a peri-urban town in southwest, Nigeria. *Environments - MDPI*, *6*(2). https://doi.org/10.3390/environments6020023

UNDER PEER REVIEW

Pierre Chegaing Fodouop, S., Francky Sohanang Nodem, S., Nsuh, L., Kamga Bogne, P., Lonang Djomsi, G., Marcel Ntsamo Beumo, H., & Yemele Mefokou, D. (2021). Physico-Chemical and Bacteriological Characteristics of Hand-Dug Wells and Boreholes Water Quality of the Vina Division, Cameroon. *Central African Journal of Public Health*, *7*(3), 136. https://doi.org/10.11648/j.cajph.20210703.17

Tabué Youmbi, J. G., Ntamack, D., Feumba, R., Ngnikam, E., Wéthé, J., & Tanawa, É. (2011). Vulnérabilité des eaux souterraines et périmètres de protection dans le bassin versant de la Mingoa (Yaoundé, Cameroun). *Revue de l'Université de Moncton*, *40*(2), 71–96. https://doi.org/10.7202/1001389ar

WAGNER, E. G., & LANOIX, J. N. (2020). *Approvisionnement en eau des zones rurales et des petites agglomérations*. WHO. https://apps.who.int/iris/handle/10665/41112

Yongsi, H. B. N. (2010). Suffering for water, suffering from water: Access to drinking-water and associated health risks in Cameroon. *Journal of Health, Population and Nutrition*, *28*(5), 424–435. https://doi.org/10.3329/jhpn.v28i5.6150

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