Microbiology Research Journal International

30(3): 74-84, 2020; Article no.MRJI.56116
ISSN: 2456-7043
(Past name: British Microbiology Research Journal, Past ISSN: 2231-0886, NLM ID: 101608140)

Assessment of Microbiological Quality of Drinking Water in Market Gardening Sites in the Centre-Ouest Region in Burkina Faso

Kaboré Aminata[1*], Savadogo Boubacar[2], Jacques Sawadogo[1], Kafando Haoua[3], Tarnagda Grissoum[2], Savadogo Windinpsidi Paul[1] and Diagbouga Serge[2]

[1]Institut de l'Environnement et de Recherches Agricoles, 04 BP 8645, Ouagadougou, Burkina Faso.
[2]Institut de Recherche en Sciences de la Santé, 03 BP 7192, Ouagadougou, Burkina Faso.
[3]Université Joseph Ki-Zerbo, 03 BP 7021, Ouagadougou, Burkina Faso.

Authors' contributions

This work was carried out in collaboration among all authors. Authors KA, KH and DS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SB, TG, JS and SWP managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/MRJI/2020/v30i330206
Editor(s):
(1) Professor, Juliano De Dea Lindner, Federal University of Santa Catarina, Brazil.
Reviewers:
(1) Syed A. Jamal, Haskell Indian Nations University, USA.
(2) Farhaoui Mohamed, National Office of Electricity and Drinking Water, Morocco.
Complete Peer review History: http://www.sdiarticle4.com/review-history/56116

Original Research Article

Received 20 February 2020
Accepted 26 April 2020
Published 04 May 2020

ABSTRACT

Microbiological quality of drinking water in market gardening sites was assessed to understand the persistence of diarrhoeal diseases and malnutrition among children under five. Households with children under five (5) were selected in Dassa, Nebia, Nariou and Tanguin-wobdo located in centre-ouest region in Burkina Faso. A total of 140 water samples were collected from storage containers in households (n=108), boreholes (n=7) and hand dug wells (n=25) during the month of February 2018. Faecal coliforms, *Escherichia coli (E. coli)* and faecal streptococci were isolated and enumerated according French standard methods. WHO standards guidelines for drinking water were used to assess water quality. Results showed that 100% of hand dug well water were contaminated with faecal bacteria whereas all water from boreholes were potables. 72% of hand

**Corresponding author: E-mail: kab.amina@yahoo.fr;*

dug well water were contaminated with *E. coli*, 96.3% with faecal coliforms and 96% with faecal streptococci. In households, 95.9% of drinking water from boreholes were contaminated with faecal bacteria versus 100% of water from hand dug wells. This situation is related to the lack of safe drinking water infrastructures, unimproved sanitation and lack of hygiene in households. In fact, 78.12% of water infrastructures were hand dug wells located mostly in gardens. In these areas, contaminated hand dug well water are used for both irrigation and consumption. Regarding these results, a reinforcement of safe drinking water infrastructures such as boreholes, improved hygiene and sanitation and health education are necessary to improve the quality of drinking water to reduce diarrhoeal diseases and malnutrition among market gardeners' children.

Keywords: Drinking water; hygiene; sanitation; waterborne diseases; bacteriology.

1. INTRODUCTION

Access to safe drinking water is a human right. However, 884 million people throughout the world do not have access to safe drinking water infrastructures and more than 2.6 billion people lack sanitation facilities [1]. Indeed, the consumption of non-drinkable water and the lack of hygiene and unimproved sanitation are at the root of many diseases [2;3]. In developing countries, 80% of all diseases are directly related to poor drinking water and unsanitary conditions [4]. 1.8 million people die each year from diarrhoeal diseases caused by the consumption of unsafe water [5]. Among them, ninety percent (90%) are children under five (5), mostly living in developing countries [5]. The diarrhoeal diseases are also a major cause of malnutrition which affect the growth and cognitive development of children [6]. In Burkina Faso, diarrhoeal diseases and malnutrition are the rank second in the causes of death of children under five after malaria [7]. According to World Health Organization (WHO), 94% of diarrhoeal episodes could be prevented by improving access to safe drinking water, hygiene and sanitation [8;9].

The access to safe drinking water in rural area remains a challenge to overcome for a sustainable development in Burkina Faso. Despite appreciable efforts undertaken to achieve the Millennium Development Goals (MDG), many people in rural areas are still suffering from the lack of access to safe drinking water [10]. The quality of water consumed by rural populations in Burkina Faso is a concern because of competition for traditional water sources such as hand dug wells. The lack of boreholes, inadequate hygiene and sanitation and lack of appropriate disinfection methods in households further worsens the problem [11;12].

In the centre-ouest region, 31.6% of population do not have access to safe drinking water infrastructures [13]. This region which is the 4th biggest producer of vegetables in Burkina Faso presents the highest prevalence of malnutrition despite the implementation of a strengthening program of food security and household incomes of market gardeners since 2015 [14;15]. In 2016, this prevalence was 9.7% among children under five (5) [14]. This situation could be linked to the consumption of non-drinkable water which could lead to diarrhoeal diseases and malnutrition among children. There is a lack of data concerning drinking water quality in these areas.

In this study, we evaluated the microbiological quality of water from boreholes, hand dug wells and those stored in households, the access to safe drinking water infrastructures, hygiene and sanitation in households and contamination factors of drinking water in these market gardening sites.

2. MATERIALS AND METHODS

2.1 Study Area

The centre-ouest region is located between latitude 10°58'N-12°50'N and longitude 1°18'W-2°55'W. It has a land area of about 21 752.48 km^2. The climate of this region is Sudano-Sahelian, marked by a long dry season lasting from October to May and a short rainy season between June and September [16]. Precipitation is irregular and scant with an annual average of 700 to 1200 mm [16]. In this region, agriculture and farming are the main economic activities of populations. These activities are organized around family farms and are traditional type. The market gardens are located around surface water reservoirs. In addition to agriculture, surface waters are used for recreational activities and animals watering. All these usage contribute to contaminate water. In these sites, drinking water access for populations is possible from various sources of supply, mainly from groundwater particulary from boreholess and hand dug wells.

Four (4) villages were involved in this study. These are the villages of Dassa, Nebia, Nariou and Tanghin-wobdo. In Dassa and Nebia, 15.58% of market gardeners' children suffered from acute malnutrition, 33.77% from underweight and 36.36% suffered from stunted growth [17]. Fig. 1 shows the location of the central-western region in Burkina Faso.

2.2 Water Sampling

In this study, only households with children under five (5) were selected. A total of 140 water samples were collected. 108 were collected from storage containers in households, 07 from boreholes and 25 from hand dug wells. Table 1 shows the distribution of samples in each site.

Water samples were collected aseptically in 500 mL glass bottles sterilized at 121°C during 15 minutes in the autoclave. The samples were transferred to the laboratory in cooled boxes and stored in a fridge at 4°C before analysis on the same day according to ISO 5667-3 standard. In addition to water sampling a questionnaire on the access to safe drinking water infrastructures, hygiene and sanitation were administered to women.

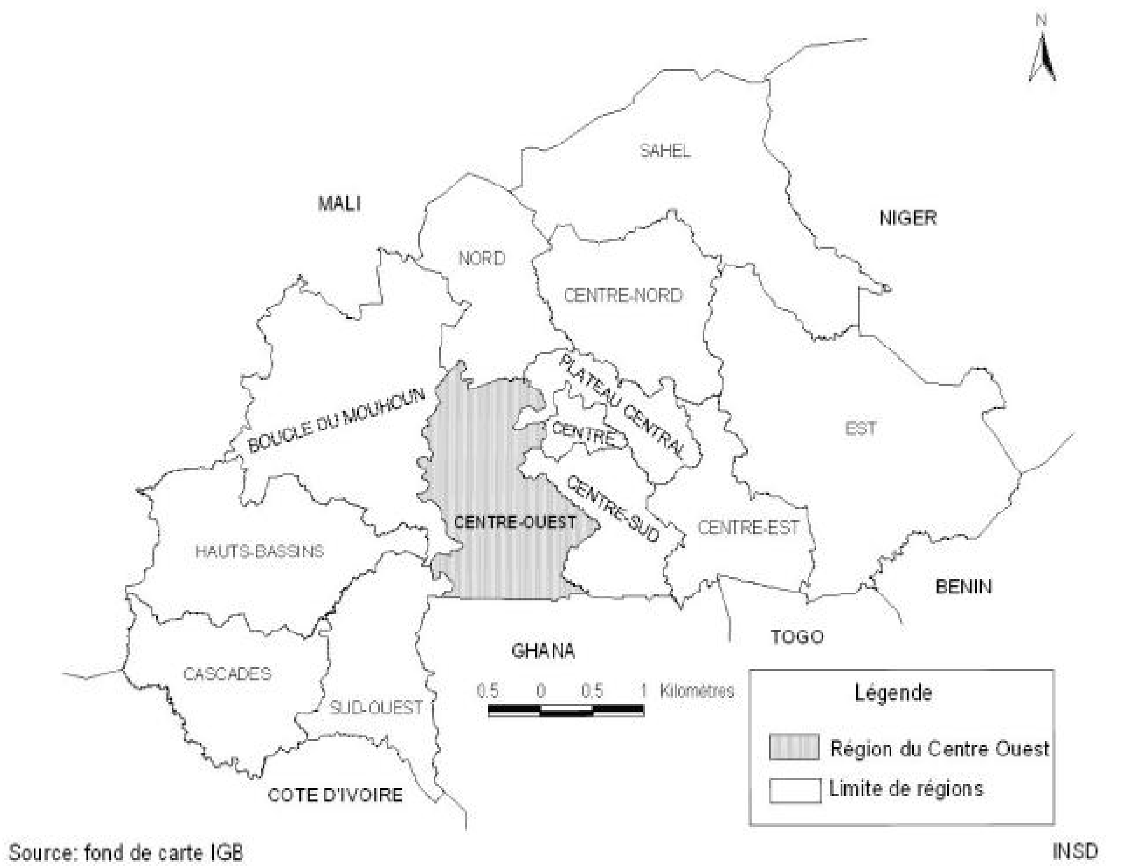

Fig. 1. Location of centre-ouest region in Burkina Faso

Table 1. Distribution of samples by village

Site	Household	Borehole	Hand dug well
Dassa	24	01	07
Nariou	38	01	02
Nebia	12	01	07
Tanguin-wobdo	34	04	09
Total	108	7	25

2.3 Microbiological Analysis of Water Samples

Three (3) bacterial indicators of faecal contamination namely *Escherichia coli (E. coli)*, faecal coliforms, faecal streptococci were determined by the method of membrane filtration technique [18]. Bacterial cells were concentrated on a 0.2 µm millipore membrane filter followed by culture on the chromogenic RAPID *E. coli* 2 AGAR (BIO RAD) medium which contains 2 substrates specific to the *β*-D-Glucuronidase (Gluc) and *β*-D-Galactosidase (Gal) enzymes, respectively. Incubation was performed at 44.5°C for 24 hours. Colonies of *E. coli* (Gal+/Gluc+) appear violet to pink while other coliforms colonies stain blue. On the bile esculine azide medium, Gram positive cells able to reduce esculine as faecal streptococci stain black after 24 hours incubation period at 37°C, while Gram negative and other Gram positive cells are inhibited by sodium azide.

3. RESULTS AND DISCUSSION

3.1 Microbiological Quality of Boreholes and Hand Dug Well Waters

The results showed that all borehole water samples were free from faecal bacteria. This indicated good quality water and safe for drinking according to WHO standards [19]. Contrary to boreholes water samples, all hand dug well water samples were contaminated with at least one faecal group of bacteria. The means faecal coliforms were ranged from 1690 to 4965 CFU/100 mL, 30 to 245 CFU/100 mL for *E. coli* and 1440 to 4875 CFU/100 mL for faecal streptococci. Fig. 2 presents the results of the microbiological parameters of boreholes and hand dug wells water samples.

The results also indicated that 72% of hang dug well water samples were contaminated with *E. coli*, 96% with both faecal coliforms and streptococci (Table 2). 76% of all hand dug well water samples were contaminated with both *E. coli*, faecal coliforms and streptococci (Table 2). The highest contents were found in hand dug well samples from Nebia, followed by those from Dassa, Tanghin-wobdo and Nariou (Fig. 2). Some studies confirm these results on the quality on hand dug well waters [20;21; 22].

The contamination of these waters is due to the poor quality of hand dug wells, the lack of hygiene around wells and the lack or unsuitability of sanitary infrastructures which lead to open defaecation [23]. Furthermore, most hand dug wells are located in vegetable gardens. In these sites, the contamination of water could come from animal excreta used for soil fertilization [24]. Regarding to the microbiological quality, these hand dug well waters consumption could cause a lot of diarrhoeal diseases among children. Unsafe drinking water contaminated with soil or faeces could act as a carrier of parasitic infections. For all these all sites, 62.5% of children who consume hand dug well waters were parasitized with Giardia, *Entamoeba coli* and whipworms in 2017 [17]. A study showed that household drinking water contaminated with faecal streptococci was associated with higher odds of total intestinal pathogenic protozoa infections in children [25].

Fig. 2. Faecal coliforms (blues) and *E. coli* (violet) on chromogenic rapid *E. coli* 2 agar

3.2 Microbiological Quality of Drinking Water Stored in Households

The results showed, a significant deterioration of microbiological quality of drinking water inhouseholds. 80% of drinking water samples presented higher contents of faecal bacteria than water from sources (boreholes or wells). The means faecal coliforms in water samples from households were ranged from 1267 to 3888 CFU/100 mL, 20 to 109 CFU/100 mL for *E. coli* and 479 to 4589 CFU/100 mL for faecal streptococci. For all drinking water samples from storage containers in households, 50% were contaminated with *E. coli* and 96.3% with faecal coliforms and 89.8% with streptococci (Table 2). Fig. 3 shows the means faecal bacteria in drinking water from households in Dassa, Nariou, Nebia and Tanguin-wobdo.

97.2% of drinking water samples from storage containers in households were contaminated with at least one faecal group of bacteria (Table 3). The contamination with two faecal groups of bacteria was observed in 91.45% water samples. In households, it also appears that 95.85% of drinking water from boreholes were contaminated with faecal bacteria versus 100% of those from hand dug wells. In Dassa, 91.7% of drinking water samples from storage containers in households were contaminated, 97.1% in Tanghin-wobdo and 100% in Nariou and Nébia. In households which are supplied by boreholes, the results show that only 4% of drinking water from storage containers were free from faecal bacteria. 11% were contaminated with one faecal group of bacteria, 41% with two faecal groups of bacteria and 44% were contaminated with both faecal coliforms, *E. coli* and faecal streptococci (Table 3). In households which get drinking water from hand dug wells, all samples from storage containers were contaminated. Thus, 34.3% were contaminated with two faecal groups of bacteria and 65.7% with both faecal coliforms, *E. coli* and faecal streptococci (Table 3). Table 3 shows the distribution of faecal bacteria in drinking water from storage containers in households.

Moreover, it appears that the contamination of drinking water from hand dug wells is more significant than those from boreholes. Hundred per cent (100%) of polycontamination has been observed for these water samples with *E. coli* as a recent indicator of faecal pollution (Table 4). The presence of faecal coliforms and *E. coli* in drinking water indicates recent faecal contamination and the possible presence of disease-causing pathogens, such as bacteria, viruses and parasites [19;26;27].

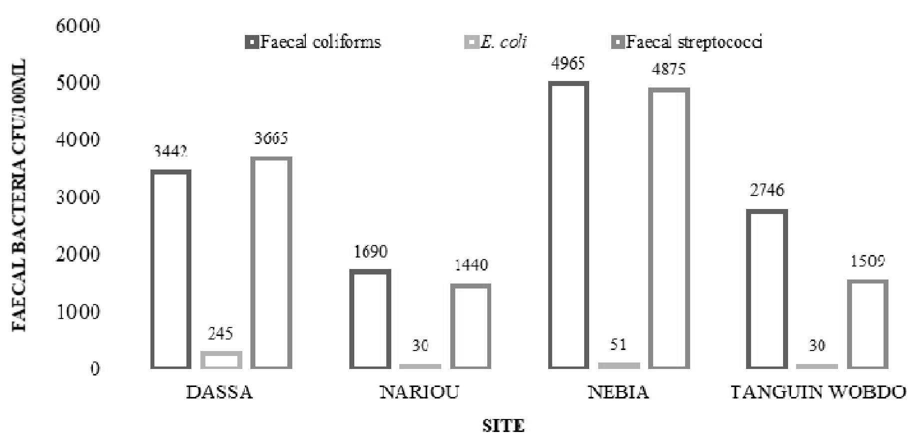

Fig. 3. Means faecal bacteria in hand dug well waters in the different sites

Table 2. Distribution of faecal bacteria in water samples from hand dug wells

Fecal bacteria		Borehole	Hand dug well	Household
Faecal coliforms	free from bacteria	100.0%	4%	3.7%
	contaminated	0.0%	96%	96.3%
E. coli	free from bacteria	100.0%	28%	50%
	contaminated	0.0%	72%	50%
Faecal streptococci	free from bacteria	100.0%	4%	10.2%
	contaminated	0.0%	96%	89.8%

Table 3. Contamination of drinking water from storage containers in households with faecal bacteria

Sample	Potable	Contaminated with one faecal group of bacteria	Contaminated with two faecal groups of bacteria	Contaminated with three faecal groups of bacteria
Water from hand dug well	0.0%	0.0%	34.3%	65.7%
Water from borehole	4.1%	11.0%	41.1%	43.8%
All sources	2.8%	7.4%	38.9%	50.9%

Table 4. Prevalence of polycontamination in drinking water samples

Water sample	Faecal streptococci + faecal coliforms	*E. coli* + faecal streptococci + faecal coliforms
Source	12.5%	49.1%
Household	39.8%	59.4%

The contamination of water in household is mainly due to the lack of hygiene. In fact, the transportation of water in households is mainly done in open containers or plastic cans which are not regularly cleaned. That is the first step of drinking water contamination. Moreover, during the drawing and storage, the good hygiene practices are not applied.

3.3 Causes of the Consumption of Unsafe Drinking Water in Market Gardening Sites

3.3.1 The lack of safe drinking water infrastructures

For all sites, hand dug wells represent 78.12% of water sources. In Dassa and Nébia, boreholes are only 12.5%, 33.3% in Nariou and 30.76% in Tanghin-wobdo (Table 5). Comparatively, hand dug wells represent 87.5% of water sources in Dassa and Nébia, 66.7% in Nariou and 69.2% in Tanghin Wobdo (Table 5). This disparity and the lack of boreholes are challenge for authorities to improve the access of safe drinking water in rural areas in Burkina Faso [10,12]. The results of the counting of boreholes and hand dug wells in each site are presented in Table 5.

3.3.2 Inaccessibility to safe drinking water infrastructures

In Dassa and Tanghin-wobdo, 95.8 and 79.4% of households get drinking water mainly from boreholes respectively, versus 57.9% in Nariou and 8.3% in Nebia (Table 6). In Nebia, 91.7% of households are mainly supplied from hand dug wells because of they are more accessible. Moreover, the usage depends on a particular moment of the day. Thus, for all sites, results showed that 93.8% of children drink hand dug well waters when mothers work in market gardens because of these are the closest. However, at home, 67.6% drink water from boreholes versus 32.4% from hang dug wells waters. So, the use of boreholes and hand dug wells depends on their accessibility and organoleptic parameters of waters. Table 6 presents the usage rate of boreholes and hand dug wells by households in each site.

3.3.3 Drinking water storage in households

The deterioration of microbiological quality of drinking water store in households is mainly due to the lack of hygiene and the inadequacy of storage containers and improper water handling [24]. The extended storage of drinking water in traditional containers could also be a factor of degradation of microbiological quality of drinking water (Fig. 4). These containers are not regularly cleaned and the accumulation of organic matter stimulate bacterial growth in water [24]. This poor quality of drinking water stored in households also reflects a lack of domestic treatment as disinfection of drinking water.

Regarding to this situation it necessary to implement some disinfection methods of drinking water as chlorination for borehole water or the usage of local plant as *Moringa oleifera* seeds to treat wells water. It is also advisable to develop preventive measures at land management and soil occupation nearby water sources, and at hygiene and basic sanitation levels as well.

Table 5. Proportion of boreholes and hand dug wells in each market gardening sites

Site	Water source	
	Borehole	Hand dug well
Nariou	33.3%	66.7%
Tanghin-wobdo	30.76%	69.23%
Dassa	12.5%	87.5%
Nébia	12.5%	87.5%

Table 6. Usage rate of boreholes and hand dug wells by households

Site	Borehole	Hand dug well
Nariou	57.9%	42.1%
Tanguin-wobdo	79.4%	20.6%
Dassa	95.8%	4.2%
Nébia	8.3%	91.7%

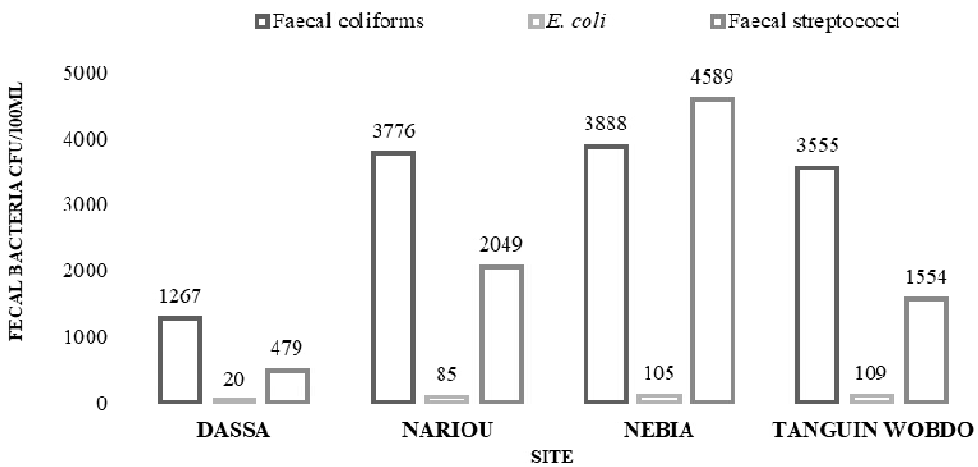

Fig. 4. Means faecal bacteria in drinking water stored in households

3.3.4 Hygiene and sanitary conditions in households

Assessment of hygiene and sanitary conditions was based on the presence/absence of latrines and domestic animals in households. Based on the findings of the questionnaires conducted with women, it appears that 68.5% of households had access to latrines versus 31.5% which did not own latrines, in all sites combined. All households in Dassa had access to latrine versus 55.3% in Nariou, 83.3% in Nébia and 55.9% in Tanguin-wobgo (Fig. 5). It appears also that 33.3% of households in Dassa breed domestic animals, 13.2% in Nariou, 8.3% in Nebia and 17.6% in Tanguin wobdo. These poor hygiene and sanitation conditions negatively impact drinking water quality in households. Fig. 5 shows the results of the possession of latrines in each village.

The results showed that drinking water from households which did not own latrines was more contaminated with faecal bacteria than those from households which had access to latrines (Table 7). Table 7 shows the means faecal bacteria in drinking water according to the possession or not of latrines and domestic animals in households.

Overall, in households which had access to latrines, 4.05% of drinking water were potable, 8.11% were contaminated with one faecal group of bacteria, 41.89% were contaminated with two faecal groups of bacteria and 45.95% were contaminated with both faecal coliforms, *E. coli* and faecal streptococci. In households which did not have access to latrines, all water samples were contaminated. Indeed, 5.88% of drinking water were contaminated with one faecal group of bacteria, 32.35% were contaminated with two faecal groups of bacteria and 61.76% were contaminated with both faecal coliforms, *E. coli* and faecal streptococci. These results indicate that the absence of latrines has a negative impact on microbiological quality of drinking water stored in households. This situation leads to open defaecation which has an impact on faecal contamination (absence of water and cleansing tissues/paper), and thus exposure to intestinal parasitic infections. These results corroborate with those of Yoni [28] which showed a correlation between the access to latrines and the contamination of drinking water with faecal bacteria in households.

Concerning the possession of domestic animals, it appears that the contamination of drinking water is significantly higher in households which breed than those which do not (Table 7). Fig. 6 presents the drinking water quality relating to the access to latrines in households.

Fig. 5. Drinking water storage in households

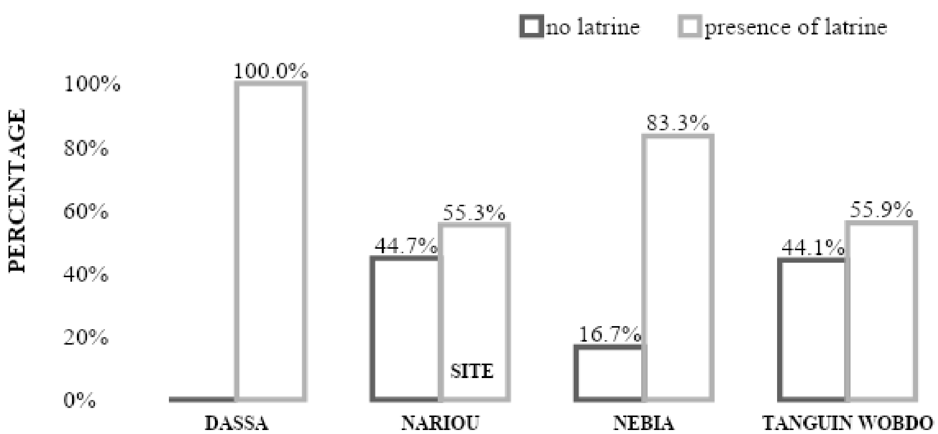

Fig. 6. Rate of access to latrines in households

Table 7. Means faecal bacteria in drinking water according to the possession or not of latrines and domestic animals in households

Faecal bacteria (CFU/100mL)	Latrines		Domestic animals	
	Absence	**Presence**	**Absence**	**Presence**
Faecal coliforms	3909	2818	3094	3459
E. coli	114	65	70	124
Faecal streptococci	2115	1694	1738	2218

In households which breed domestic animals, only 2.05% of drinking water were potables versus 5% for those which did not breed. 9.09% of drinking water were contaminated with one faecal group of bacteria, 39.77% were contaminated with two faecal groups of bacteria and 48.89% were contaminated with both faecal coliforms, *E. coli* and faecal streptococci. In households without domestic animals, 35% of drinking water were contaminated with two faecal groups of bacteria and 60% with both faecal coliforms, *E. coli* and faecal streptococci. These results show that the presence of domestic animals in households is a major source of contamination of drinking water.

Overall, in households without sanitation facilities, the proportion of parasitized children was 57.14% versus 45% for those with sanitation facilities [17]. Thus, the absence of latrines, unimproved sanitation and lack of hygiene, particularly hand washing after defaecation, lead to the contamination of drinking water and increase the risk of waterborne diseases. Fig. 7 presents the drinking water quality relating to the possession of domestic animals in households.

This cross-sectional study showed that various interventions have to implement for an effective consumption of safe drinking water to fight against waterborne diseases and children malnutrition in market garden sites. First, it is required to take account the realization of water supply infrastructures in development projects and programs in the field of food safety in these sites. Secondly, our findings call for international and local action to provide funding to build latrines and other sanitation facilities. WASH and health education interventions like hand washing should be implemented to reduce transmission of pathogenic germs. In household level, the treatment of drinking water is necessary. For that, some disinfection methods like sand filtration, boiling, and chlorination with bench should help to get safe drinking water.

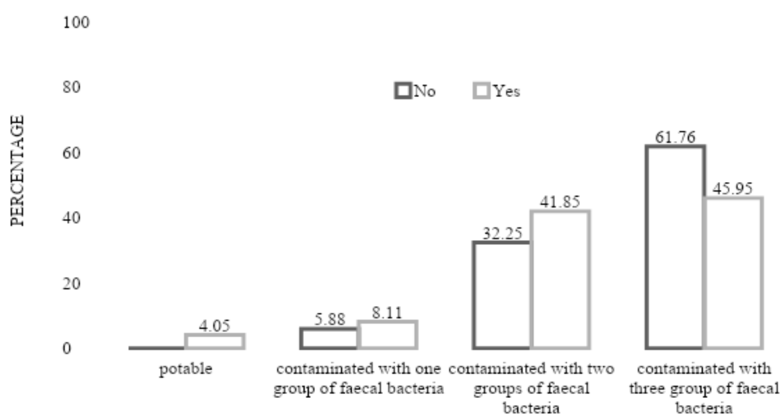

Fig. 7. Drinking water quality relating to the access of latrines in households

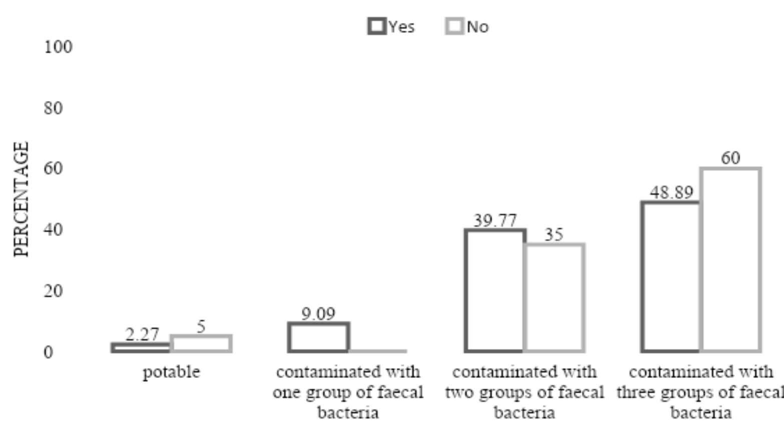

Fig. 8. Drinking water quality relating to domestic animals breeding in households

4. CONCLUSION

Unsafe drinking water, unimproved sanitation and lack of hygiene pose health risks, particularly to children in low and middle-income countries. The poor quality of water consumed by market gardeners in the centre-ouest region is related to water source quality, poor hygiene and sanitation conditions and inadequate storage in households. The high contents of faecal bacteria in drinking water increases the risk of diarrhoeal diseases and malnutrition in children under 5. Regarding to these results, it is necessary to build more boreholes and sanitation infrastructures and associated health education in all development program in market gardening sites for an effective access to safe drinking water. This could help to fight diarrhoeal diseases and malnutrition among children under 5.

CONSENT

As per international standard written participant consent has been collected and preserved by the authors

ETHICAL APPROVAL

It is not applicable.

ACKNOWLEDGEMENTS

The authors thank Mrs Paul BAYILI leader of the GEDES-APIPAC consortium and Cheick KANAZOE, manager of PAMEFA program. The study was supported by the Swiss cooperation funding. We are gratefull to all market gardeners for their collaboration.

We thank Pr Guéladio CISSE at the Swiss TPH, Basel, Switzerland for his advice and guidance in the design of the research and the proofreading of the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. International solidarity. Barometer of water, hygiene and sanitation: inventory of access to a vital resource. 4th edition; 2018.
2. Somé Y, Soro T, Ouédraogo S. Study of the prevalence of waterborne diseases and influences of environmental factors in the Nongr-Masson district: case of Tanghin district. Int. J. Biol. Chem. Sci. 2014;8(1): 289-303.
3. Ledeur S. Use of a geographic information system as a tool for understanding waterborne epidemics and as a decision support tool: study in an urban context, Ouagadougou, Burkina Faso. Master thesis in sanitary engineering, National School of Public Health, Rennes; 2004.
4. Adekoyeni O, Salako S. Microbiological, physicochemical and mineral quality of borehole water in Ijebu Land, Ogun State, Nigeria. International Journal of Science and Advanced Technology. 2012;2:23-30.
5. World Health Organization. Fight waterborne diseases at home. The WHO Newsletter; 2007.
6. Guerrant LR, Oria RB, Moore SR, Oria MOB, Lima AAM. Malnutrition as an enteric infectious disease with long-term effects on child development. Nutri Rev. 2008;66(9):487-505.
7. SOME SMY. Acute diarrhea in children in a hospital environment in Burkina Faso from 2008 to 2011: epidemiological-clinical, etiological, therapeutic and progressive aspects. Medicine thesis, University of Ouagadougou, Burkina Faso; 2011.
8. Pruss A, Corvalan C. Preventing disease through healthy environments: Towards an estimate of the environmental burden of disease. World Health Organization; 2006.
9. Clasen T, Roberts I, Rabie T, Schmidt W, Cairncross S. Interventions to improve water quality for preventing diarrhoea. Cochrane Database of Systematic Reviews. 2006;3:1-117.
10. National program ofdrinking water supply by 2030. 2017 national report. Ministry of water and sanitation, Burkina Faso; 2018.
11. Dianou D, Savadogo B, Zongo D, Zougouri T, Poda JN, Bado H, Rosillon F. Surface waters quality of the Sourouvalley: The Case of Mouhoun, Sourou, Debeand Gana Rivers in Burkina Faso. International Journal of Biological and Chemical Sciences. 2011;5(4):1571-1589.
12. Ministry of Agriculture. National program of drinking water supply for the 2015 year issue. Direction of Hydraulics Resources Inventory, Hydraulics and Fishing Resources. 2006;43.

13. Directorate General of Water Resources. Report of the 22nd session of regional steering committee of the national program for drinking water supply and sanitation in the Central West region in Burkina Faso; 2018.
14. National Observatory of Employment and Training. Update of the study on niche job carriers in the central west region; 2014.
15. Ministry of Health. Provisional results of the nutritional survey; 2016.
16. Ministry of Agriculture and Hydraulics. National survey of household access to family sanitation facilities: Central plateau regional monograph; 2011.
17. Onadokun B. The determinants of nutritional status in children from 06 to 59 months involved in PAMEFA project in DASSA and NEBIA in the Central Western region of Burkina Faso. Medicine thesis, University of Joseph KI-ZERBO, Burkina Faso; 2018.
18. American Public Health Association. Standard Methods for the Examination of Water and Wastewater, 20th edition. American Public Health Association, American Water Works Association and Water Pollution Control Federation, Washington; 1998.
19. World Health Organization. Guidelines for drinking water quality. Fourth Edition.Geneva; 2011.
20. Makoutode MAM. Quality and well water use in rural areas in Benin: Case of the sub-prefecture of Grand Popo. Black African Medicine. 1999;46(11):528-534.
21. Ndounla J. Biological and physico-chemical characteristics of drinking water and influence of the mode of supply on the health of populations in Dschang. Master's thesis of Sciences, University of Dschang; 2007.
22. Koné B, Doumbia M, Adji FX. Ecosystem approach to the management of diarrheal diseases in peri-urban areas: Case of a lagoon village in the town of Yopougon (Abidjan-Ivory Coast). Final Report of Switzerland TPH Project; 2007.
23. Savadogo B, Kaboré A, Zongo D, Poda JN, H. Bado H, Rosillon F, Dianou D. Problematic of drinking water access in rural area: Case Study of the Sourou Valley in Burkina Faso. Journal of Environmental Protection. 2013;4:31-50.
24. Franck Lalanne. Study of water quality along the supply chain at consumer level in 10 villages in the province of Ganzourgou (Plateau Central region, Burkina Faso). International Institute for Water and Environmental Engineering (2iE), Burkina Faso; 2012.
25. Erismann S, Diagbouga S, Odermatt P, Knoblauch AM, Gerold J, Shrestha A, Tarnagda G, Kaboré A, Schindler C, Utzinger J, Cissé G. Prevalence of intestinal parasitic infections and associated risk factors among schoolchildren in the Plateau Central and Center-Ouest regions of Burkina Faso. Parasites & Vectors. 2016;9(554):1-14.
26. Strunz EC, Addiss DG, Stocks ME, Ogden S, Utzinger J, Freeman MC. Water, sanitation, hygiene and soil-transmitted helminth infection: A systematic review and meta-analysis. PLoS Med. 2014;11: e1001620.
27. Speich B, Croll D, Fürst T, Utzinger J, Keizer J. Effect of sanitation and water treatment on intestinal protozoa infection: a systematic review and metaanalysis. Lancet Infect Dis. 2016;16:87–99.
28. Yoni RMD. Assessment of water quality in municipalities located in outskirts areasof Ouagadougou: case of Saaba, master's thesis, International Institute for Water and Environment Engineering, Burkina Faso; 2014.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/56116