Asian Journal of Geographical Research

3(4): 103-115, 2020; Article no.AJGR.63767
ISSN: 2582-2985

GIS Approach for the Analysis of the Socio-Sanitary Stakes of Water Use in the Lobo Watershed in Nibehibe (Central-Western Côte d'Ivoire)

Arthur Brice Konan-Waidhet[1*], Fanraban Fabrice Toure[1], Ali Diarra[2], Affoue Berthe Yao[1], Tano Jean Jacques Koua[1] and Mahamadou Koita[3]

[1]Environmental Sciences and Technologies Laboratory, Jean Lorougnon Guede University, Daloa, Cote d'Ivoire.
[2]Coastal, Sea, Health, Food Safety and Transport Laboratory, Jean Lorougnon Guede University, Daloa, Côte d'Ivoire.
[3]Water, Hydrosystems and Agriculture Laboratory, International Institute of Water and Environmental Engineering, Ouagadougou, Burkina Faso.

Authors' contributions

This work was carried out in collaboration among all authors. Author ABKW designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors FFT and AD managed the analyses of the study. Authors ABY, TJJK and MK managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJGR/2020/v3i430121
Editor(s):
(1) Dr. Hani Rezgallah Al-Hamed Al-Amoush, Al al-Bayt University, Jordan.
Reviewers:
(1) Pramod Kumar Anthwal, OPJS University, India.
(2) M. V. S. S. Giridhar, Jawaharlal Nehru Technological University, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/63767

Original Research Article

Received 03 October 2020
Accepted 09 December 2020
Published 22 December 2020

ABSTRACT

Water is a precious natural resource that is essential for many uses, but its quality is faced with several problems, including pollution linked to human activities, hence the need to contribute to improving the quality of drinking water. Given the importance of the resource, the health of the population in terms of hygiene needs and the quality of the water consumed is paramount. It is within this framework that this work falls within the scope of this project, the objective of which is to analyze the health impacts to which the populations are exposed due to the use of water in the Lobo watershed in Nibéhibé. To achieve this objective, the working method was based on literature review and field surveys. The documentary research consisted in circumscribing the contours of the subject in order to better understand it. As for the field surveys, they were dominated by interviews

**Corresponding author: E-mail: konanwab@yahoo.fr, arthurwaidhet@gmail.com;*

and a questionnaire addressed to households and health structures. Using the simple random selection method without discount and the use of a statistical equation, we found a sample of 384 households to be surveyed, distributed in three departments (Daloa, Vavoua and Zoukougbeu). Population surveys, combined with spatially referenced data under GIS, made it possible to assess not only the spatial distribution of the importance of water-related diseases, but also the areas at health risk. The results highlighted health risk indicators that expose households to water-related diseases linked to the mode of water supply. Also, the contraction of these diseases by households is due to the uncontrolled use of multiple uses and the risky behavior of the population with regard to hygiene and sanitation practices. In addition, we note that those in rural areas are the most affected because of the insufficient level of access to drinking water and adequate sanitation. Thus, these diseases cause great loss of human life and contribute to the disorganization of the social structure.

Keywords: Access to drinking water; watershed; socio-health issues; GIS; risk assessment; lobo.

1. INTRODUCTION

Water is a limited natural resource, necessary for life and socio-economic development [1]. With population growth, galloping urbanization and climate change, having water available in sufficient quantity and quality contributes to maintaining health [2]. Demand is increasing and water resources are increasingly degraded. Moreover, improving people's living conditions requires better access to the first basic service, water [3]. Being able to obtain drinking water is a basic need and, therefore, a fundamental right [4]. Thus, the Millennium Development Goal (MDG) related to water and sanitation set by the United Nations was to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation [5]. However, achieving these goals remains a major challenge for our States. Indeed, efforts to find solutions to the issue of access to drinking water are long overdue. As proof, since the 1970s, the issue of access to essential services has gradually become part of the international agenda through a series of events [6]. Indeed, its quality is a universal health problem [7]. To this effect, the lack of drinking water supply, hygiene and sanitation is at the root of many diseases, including diarrhoea, which is contracted by 2.4 billion people per year worldwide and causes more than 2.6 million deaths annually [8]. In Côte d'Ivoire, the proportion of households with access to safe drinking water rose from 46 percent in 1998 to 51.2 percent in 2002 and to 61 percent in 2008, an increase of about 10 percentage points over a decade [9]. In the Lobo watershed, particularly in Daloa, the economic hub of the Upper Sassandra region, which is the most important cocoa-producing area, the population faces a series of ongoing difficulties related to the need for drinking water. These difficulties are related not only to the availability of these resources but also and above all to the recurring qualitative and quantitative problems that affect more vulnerable and destitute populations in the underprivileged neighborhoods of Daloa [10]. In addition, the intermittency of water distribution and the deterioration of its colouring forces the population to turn to other inappropriate alternative water sources. However, the insalubrity around these water points as well as the conditions for collecting, transporting and storing water deteriorate its quality and thus expose the population to health risks, especially in areas without drinking water sources [11]. Thus, despite all these actions, there are still shortcomings in terms of access to water with consequences on the health of the population. The present study aims to assess the health impacts to which the populations are exposed in relation to the use of water resources in the Lobo watershed in Nibéhibé.

2. MATERIALS AND METHODS

2.1 Study Area

The Lobo watershed is located in central-western Côte d'Ivoire between 6°17' and 6°44' W longitude and between 6°46' and 7°41' N latitude (Fig. 1). It drains an area of 7,000 km² with an outlet at Nibéhibé. This watershed has a catchment area that is not circumscribed within a single administrative entity. Most of the basin covers the departments of Daloa, Issia, Vavoua, and Zoukougbeu. The Lobo river has its source at an altitude of 400 m south of Séguéla and flows into the Sassandra river not far from the locality of Loboville. The town of Daloa represents the economic pole of the region.

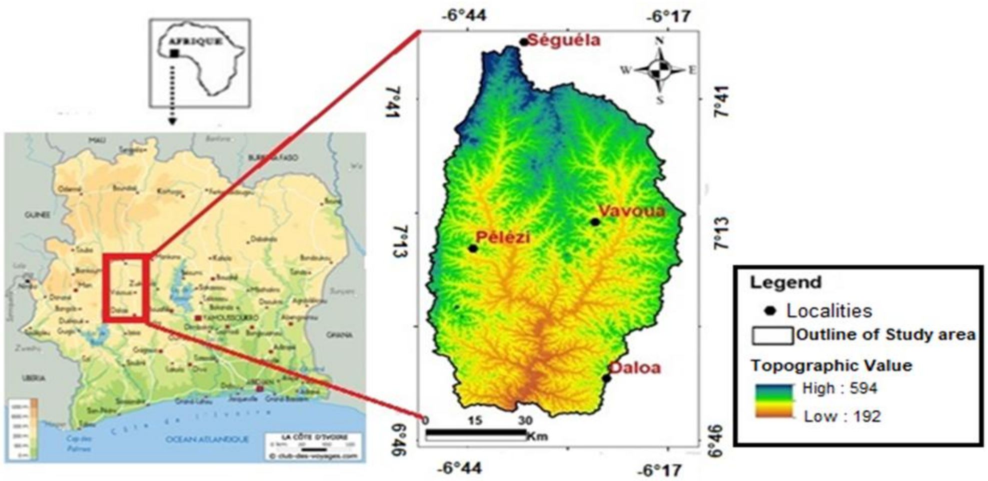

Fig. 1. Location of the Study area

Economic activities are quite diversified, however agriculture remains the main income-generating activity practiced by the majority of the population. The agricultural dynamic is based essentially on perennial cash crops (coffee, cocoa, rubber, oil palm), food crops and market gardens. The agricultural system, initially extensive, is now evolving towards a much more intensive agriculture due to the increasing scarcity of arable land. Animal husbandry is a secondary activity in the region.

2.2 Data Collection

The data concerns information on the socio-sanitary stakes of the use of water resources in the different localities and was collected through a questionnaire survey and interviews conducted with stakeholders in the Lobo watershed whose outlet is in Nibéhibé. A Garmin GPS was used to take the geographical coordinates of the localities in order to spatialize them. A digital camera was used to take pictures as well as survey sheets. In the field, the surveys were carried out in two phases : a first phase devoted to households and a second phase devoted to health structures. The objectives of the surveys were to evaluate the main health problems of the population as well as the environmental and socio-sanitary risk factors. They made it possible to identify water supply sources and household waste disposal methods. We chose open-ended questions because they have the advantage of eliciting new questions and broadening discussions. Individual interviews with the heads of households were held on the basis of indirect and direct questions. In order to conduct the survey properly, sampling was carried out. It should be noted that the sampling technique used the method of reasoned choice and proportional calculation. The household sample size (n) was obtained using the following formula [12,13]:

$$n = d^2 * p * (1-p) * c / i^2$$

where :

- d = standard deviation that corresponds to the risk α consented to ; the error of precision of the estimate is usually 5%, which gives d = 1.96
- p = estimated prevalence of the health problem or phenomenon being studied ;
- i = margin of sampling error tolerated at 5% ;
- c = correction factor, generally chosen as equal to 1.

Malaria and diarrheal diseases are known to be the major environment-related health problems in Daloa. Since we do not have reliable data on the prevalence of diseases in the population, we considered a maximum p prevalence of 50% for malaria, which is the more prevalent of the two diseases, and used it for the sample calculation. Thus, a sample of 384 households was selected for our surveys, which took place between March and April 2019 and were distributed throughout the entire catchment area.

2.3 Data Processing

We first had to go through our questionnaires, interview guide, interview, map, photos, and notebook. The purpose of this part of the work is to organize the information by theme in order to identify the main axes of analysis. In a second part, the processing of the various data collected through our questionnaire and guide, required the use of Excel and ArcGIS software. Indeed, the demographic and statistical data were processed by the Excel spreadsheet to produce tables and graphs. And finally, ArcGis software was used to facilitate the processing of shape files containing the boundaries of the Lobo watershed in order to extract the study area and the different localities. It was also used for the realization of the different thematic maps.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Modes of access to water resources

The populations of the localities surveyed in the Lobo basin have a diversity of water supply sources, namely: Hydraulic pumps, wells, naturel source of water water, marigots, SODECI, Water fountain bollard, the proportion of which is shown in Fig. 2.

As shown in Fig. 2, the proportions of source water uses are presented. In total, 54.94% of households use traditional wells; 17.70% of households obtain drinking water through SODECI; 17.70% use water from village boreholes. In addition, 6.76% of households obtain their water supply from developed water sources, compared to 1.5% who use water from ponds and 1.4% who use standpipes. This distribution shows an almost equal proportion of water from SODECI and boreholes, while the number of developed sources is reduced. Overall, the majority of households rely on unreliable quality resources such as traditional wells, marigots, and improved springs for their daily water supply. Drinking water from SODECI and boreholes is often lacking in some localities. However, it should be noted that according to our surveys, households generally have a poor perception of the quality of water distributed by SODECI in both rural and urban areas (Fig. 3).

Indeed, the analysis of Fig. 3 reveals that 83% of the households consider this water to be of poor quality, 13% find the water quality of this structure average and only 4% have a good appreciation of the water quality of this structure. Indeed, there is a deposit of debris at the bottom of the storage containers, a reddish color of the water, and very regular water cuts by SODECI. This is obviously one of the reasons why some households turn to alternative water sources.

3.1.2 Water management risk

Several factors subject households to water-related health risks. These include: the collection and transportation of water from the source to the home, the use of water through its storage.

3.1.2.1 Mode of water collection and transport

In our study, the households surveyed in the localities considered (rural and urban areas) use several collection and transport methods that subject the water to pollution (Fig. 4, Fig.5).

For the populations, the 25 L canisters, which are considered less exposed, are not emptied daily (Fig. 4), because for them, a canister used to collect water is not dirty. In the majority of localities, households use open containers to collect water (Fig. 5). Typically, it is the households that use communal water points (standpipes, water pumps, vendors). In addition, traditional well water collection is done using a well pit that is highly exposed to pollution. The sump is placed on the ground without a minimum of hygienic conditions. The water from the natural springs is bathed in an unhealthy immediate environment. This lack of hygiene jeopardizes the quality of this water. Consequently, the water undergoes several processes before it is consumed in households. Each stage represents risks of water pollution that can cause diarrheal diseases. In addition, Fig.6 highlights the containers used by households to collect drinking water. We find that 28.80% of households in rural areas use canisters as water collection containers, 23.91% use open buckets, 41.30% use basins and 5.97% use barrels. On the other hand, 12.68% of urban households use jerry cans for water collection, 10.50% use buckets, 64.49% use basins (open containers) and 12.31% use barrels. This figure also shows that basins and canisters are the most common means used by households for water collection in both rural and urban areas. However, the water collected in uncovered buckets and basins seems to be more exposed than that contained in canisters and barrels.

Water transport is another factor in the exposure of household drinking water to pollution. In the catchment area, households using collective water points are most affected. According to the proportion of households that transport water, 38.02% use an appropriate mode (closed container) versus 62.23% use an inappropriate system (open container). These are subject to pollution through the contact of dirty hands and make them vulnerable to dust and also flies (Fig. 5). In general, without handles, the basins hoisted on the head do not prevent fingers from contaminating the water. In addition, these households travel considerable distances to reach their homes.

3.1.2.2 Storage mode

The field survey revealed that households are implementing a water conservation system prior to consumption. Fig. 7 highlights the containers used for water storage. The results show that several types of containers are used for water conservation. These include jars, metal basins, barrels and canisters, with a high use of jars and basins in both rural and urban areas. Indeed, for households living in rural areas, the use of jars as water conservation containers is an appropriate practice for cooling water. However, in urban areas, some households use refrigerators for water preservation.

Thus, how drinking water is conserved is an important step in the preservation of water quality. The nature of the container, the shelf life and the hygiene of the water drawing cups constitute risks of water pollution. In addition, in order to avoid dirt and protect against diarrhoeal diseases, the majority of households visited reported washing their storage containers (Fig. 8). To this end, it appears that more than half of the households (70%) use soap to clean storage containers. Some households (23%) said they wash them without soap because for them the smell of soap remains in the stored water. The rest of the households (7%) do not feel obliged to wash the containers. The observation also revealed that drinking water is stored in separate locations depending on each household's design and organization.

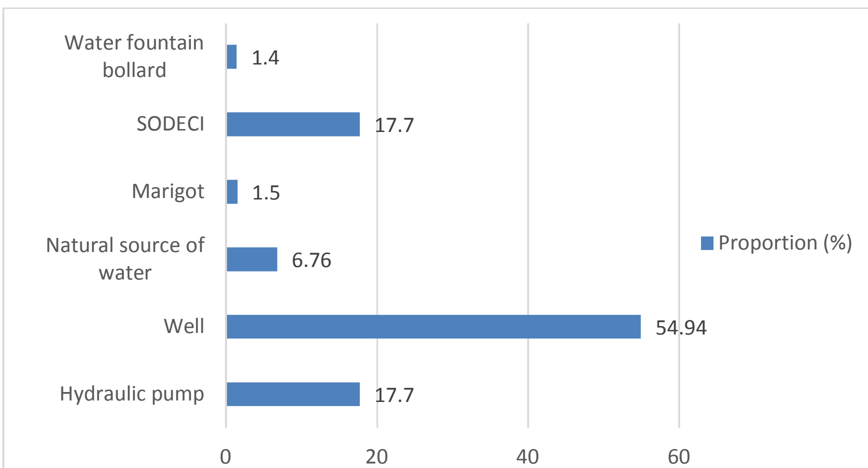

Fig. 2. Proportion of use of various water sources

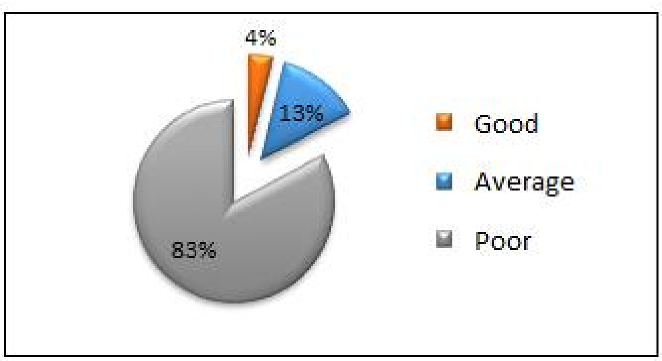

Fig. 3. Assessment of SODECI's water quality

Fig. 4. Children collecting water at a hydraulic pump in an elementary school in Pélézi

Fig. 5. Children carrying water from an open container in Banoufla

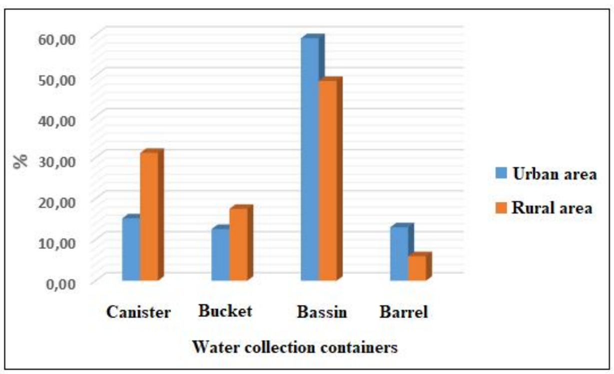

Fig. 6. Proportion of Containers used by households for water collection

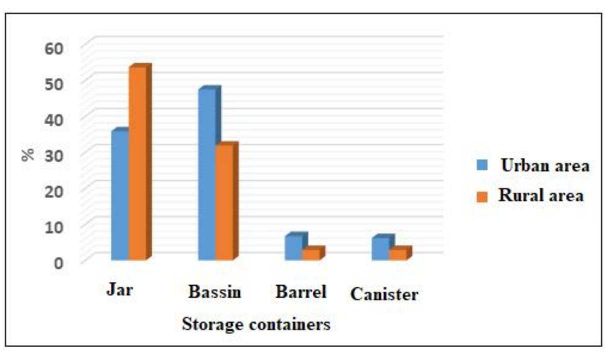

Fig. 7. Type of drinking water storage containers

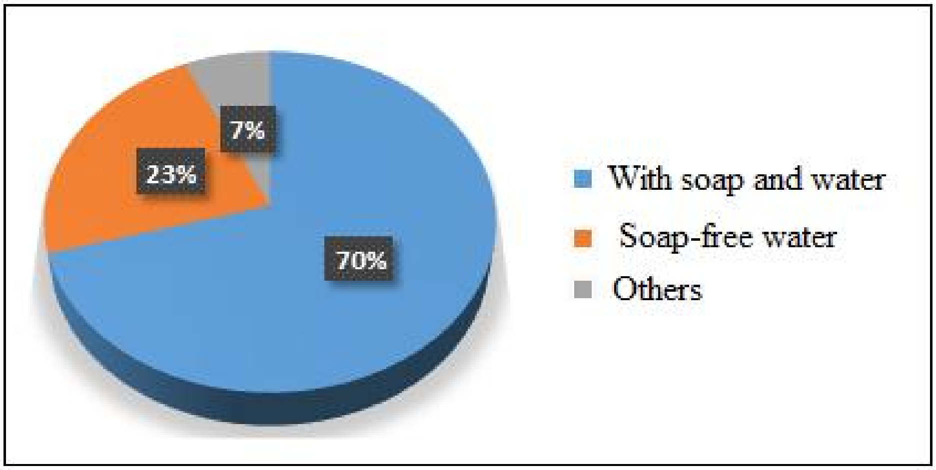

Fig. 8. Mode of cleaning of the storage containers of the water of Beverage

3.1.2.3 Drinking water treatment

The search for water potability is a constant concern, particularly in rural areas where the resource is often uncontrolled, but also in urban areas. In fact, the traditional wells used by the households surveyed are not very efficient in terms of treatment. The majority of households do not treat the water collected before consumption (Table 1). 26.30% of households treat the water by adding bleach grains. A few of the households surveyed said that they seek the services of an agency to disinfect traditional wells with a hygienic product every three months. 20, 83% of the households use filtering techniques before consuming water while for a large majority (52.86%) there is no means of water treatment.

3.1.2.4 Hygiene around water points

The insalubrity of some water points exposes the population to a number of pathogens that can contaminate the water collected, especially since women and children subjected to this task do so without precaution and sometimes with uncovered containers (basins). In addition, the lack of latrines in rural areas (Fig. 9) and the systematic use of open defecation by villagers are major sources of water point contamination.

Indeed, the survey results reveal a primacy of the traditional sanitation system that households use for their needs. This includes traditional latrines based on lost wells and open defecation (in the wild). Consequently, modern sanitation (WC) from septic tanks is used by a minority of households.

3.1.3 Health problems and importance of water-related diseases

3.1.3.1 Proportion of illnesses reported by households

The purpose of the household survey is to establish the link between water-related illnesses and difficult access to water according to the localities surveyed (Table 2).

Table 1. Type of drinking water treatment by source in households

Type of treatment	Injection of bleach grain		Filtration		No treatment		Number
	Number	%	Number	%	Number	%	
Tap water	15	14,85	25	31,25	54	26,60	94
Streams and Rivers	2	1,98	1	1,25	4	1,97	7
Traditional Drilling and Boreholes	84	83,16	54	67,5	145	71,43	283
Total locations	101	**26,30**	80	**20,83**	203	**52,86**	384

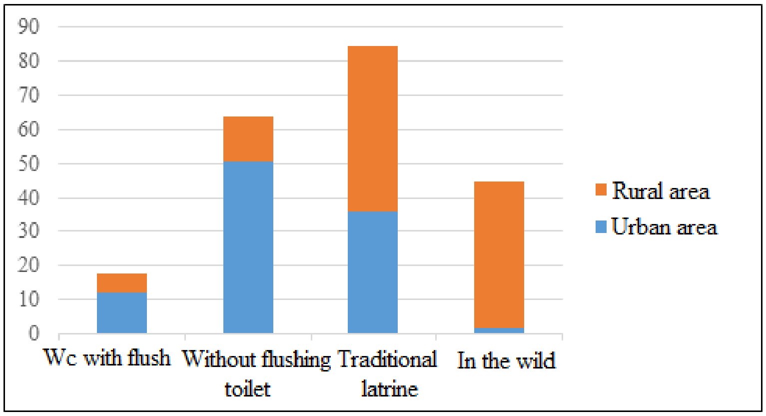

Fig. 9. Mode of cleaning of the storage containers of the water of Beverage

Table 2. Proportion of cases of illness recorded in households

Area	Identified diseases											
	Malaria		Diarrhea		Headaches and vomiting		Bilharziasis		Typhoid Fever		Anemia	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Rural area	70	44,02	48	30,18	10	6,28	5	3,14	17	10,69	9	5,66
Urban area	120	53,33	50	22,22	28	12,44	0	0	17	7,55	10	4,44
Total	190	**49,48**	98	**25,52**	38	**9,90**	5	**1,30**	34	**8,85**	19	**4,94**

Table 2 provides a ranking by the type of diseases identified in the households. At the scale of the basin, malaria diseases represent the most dominant morbidity, with 49.48% of households claiming to be regular victims of this pathology because of the wastewater that flows or stagnates in the concessions and in the streets, which are real sources of parasitic diseases. The second most prevalent disease is diarrheal morbidity, which frequently affects 25.52% of households. With regard to the first two cases, and the most dominant ones, the urban area has the sad privilege of occupying first place ahead of rural areas. The third most important place is reserved for headaches and vomiting (9.90%), which are water-borne diseases sometimes caused by the use of unsafe water. Next come cases of typhoid fever (8.85%), followed by anemia (4.94%) and finally Bilharzia.

3.1.3.2 Mapping health issues at the watershed level

Fig. 10 shows disparities in the spatial distribution of waterborne disease cases across the watershed (rural and urban) collected from health services. In addition, Fig. 10 shows the number of reported cases with signs of illness seen. Malaria presents as many cases as possible in all the localities identified with more than 1000 cases for a rate of 92% of patients. The other cases of diseases represent a lower part of the declared cases ranging from 0 to 99 cases and from 100 to 1000 cases. This is also due to the low rate of drinking water supply dominated by the use of water from traditional wells. Certain practices related to water supply modes and behavior (collection via resellers subscribing to distribution networks, transportation, heavy reliance on traditional sanitation, an inculture of hand washing with soap, heavy reliance on peasant wells, etc.) help explain these differences.

In addition, Fig. 11 shows a differentiation of health risk levels in the zones. In fact, three (3) categories of space can be distinguished. These are the areas with high, medium-high, and low health risks, and those with low or low health risk appearance.

Spatially, the Western and Central zone of the basin includes the first category of high-risk areas. In these residential areas, households have a low level of access to drinking water for domestic needs, either due to lack of financial means or lack of water treatment before consumption. They face a high health risk because the coverage of drinking water needs is extremely difficult in these spatial entities.

The second category concerns the northern and southern basin areas which have a medium level of risk. In the northern zone, households have an average level of health problems, because despite the absence of basic services at the water supply connection to the network, the populations engage in hygienic practices. This expose them less to health risks. As a result, households are less at risk when using water from traditional wells. At the level of the southern zone, the levels of health problems vary from one area to another, taking into account the variables of access to water, the level of education of households and the financial means that allow access to water of sufficient quality and quantity.

The third category concerns the eastern zone, which has a low level of risk because its populations are subject to practices aimed at ensuring reliable access to water with the variables of quality, quantity and distance-time.

3.2 Discussion

3.2.1 Water use and diseases

The results of the investigations revealed links between the constraints related to access to water and the associated health risks. This has shown that the difficult access to drinking water in both rural and urban areas exposes populations to health risks. Other factors such as the lack of hand washing with soap, the use of individual sanitation (lost wells, defecation in the countryside, in the gutters, etc.), and domestic hygiene have helped explain the distribution of cases of waterborne diseases. Water quality is determined by several indices. In the case of this study, sources whose installation has been the subject of a hygiene study (hydraulic pump and standpipe), or those that are regularly treated for potability (SODECI), are considered potable. Indeed, the use of unreliable water resources in the watershed is justified for some households by the lack of financial means and for others by the absence of a SODECI water supply in their localities and its quality which they consider doubtful. Thus, many households are supplied with well water that does not meet the quality of drinking water according to World Health Organization (WHO) standards, causing real public health problems [14]. In addition, apart from a few wells located in the lowlands of certain rural and peri-urban areas that offer a permanent service, most of them unfortunately suffer from climatic hazards. This situation exposes households, and particularly women, to the various risks associated with the search for water. In addition, some populations very often resort to resellers. However, the fact remains that this water trade constitutes a real danger to the health of the populations, due to the uncertainty of hygiene and sanitation conditions [15]. Some authors [16,17], maintain that the failure of the drinking water supply system, particularly the intermittent nature of the arrival of water in the concessions, the distance between housing and water points, the time of access to water and even the insufficient quantity of drinking water/h/d, constitute health risk factors for the populations. The distance of water points from the place of residence is an indicator of household exposure to health risks. The further the water points are from the concessions, the more households are subject to the weight of water, and the less water is available in households. The closer the water supply points are, therefore, a sign of security, especially for women and children, for whom this burden is more likely to be borne. Distance increases the risk of pollution of drinking water through faecal coliforms and thus an increased risk of contracting diarrhea. [18] cited by [19] was able to show from a study carried out in Bangadesh that beyond 200 metres between the dwelling and the collective water point, the health impact of the water supply ceases to be significant. In the Lobo catchment area, considering the distance variable, several households are subject to health risks, 26.67% of which in rural areas travel more than one kilometer and 30.84% in cities travel more than 500 meters to reach their main water point. Users who use collective water points (VH or resellers) are the most concerned. Also, households, especially in rural areas, have adopted a system of conserving drinking water in areas of the concession before consumption. Thus, as highlighted by the work of [20] at the Abidjan district level, household water storage, a source of quality degradation, is increasingly practiced by households in order to overcome drinking water distribution difficulties. However, this type of water storage condition is not always good and increases the risk of water contamination. Indeed, a study conducted by [21] in Burkina showed that after 18 hours of storage, all storage containers had an average faecal coliform count of more than 22 units per 100 milliliters, regardless of the container used for transport and storage". As for the use of water for drinking, children are the most exposed because they use cesspools themselves to drink without any hygienic provisions. These findings make unsafe water the second leading cause of child mortality worldwide [22]. In addition, the proximity of wells, the main source of household drinking water supply, to septic tanks could cause contamination of well water from underground flows [23]. There is therefore a close relationship between waterborne diseases and the use of water unfit for consumption. As an implication of these results, the logic isthat the issue of water should be addressed at the forefront of development projects. Thus, for [24], it is advisable to organise explanation sessions with households on the modes of contamination of water-related diseases in order to induce behavioural changes with regard tothe risks related to bad behaviour during water transport and storage.

3.2.2 GIS and epidemiology

GIS is of paramount importance in such a study. The establishment of a database allows authorities at various levels to have an idea of the distribution of these diseases in order to make useful decisions for the happiness of the population. The GIS has thus made it possible to clearly visualize the areas at risk and the importance of water-related diseases. This work thus provides public health officials (Minister, Regional Directors) or for any other field of intervention, with the decisive elements to make relevant and effective decisions [25]. The use of a geographic information system thus becomes a priority for those who have to manage and analyze data of an epidemiological nature, as well as for the services responsible for managing health intervention in the field [26]. More than any other tool, GIS technology makes it possible to highlight trends, correlations and interrelationships between the environment and health. As such, it is an excellent means of visualizing and analyzing epidemiological data [27]. GIS has been used in the study of several diseases, notably that conducted by [28] in the epidemiological surveillance of cholera in seven precarious districts in the city of Abidjan (Côte d'Ivoire) or that conducted by [29] forthe study of bilharzian risk in Schistosoma mansoni in the sub-prefecture of Manandriana in Madagascar using the coupled Geographic Information System and Remote Sensing method.

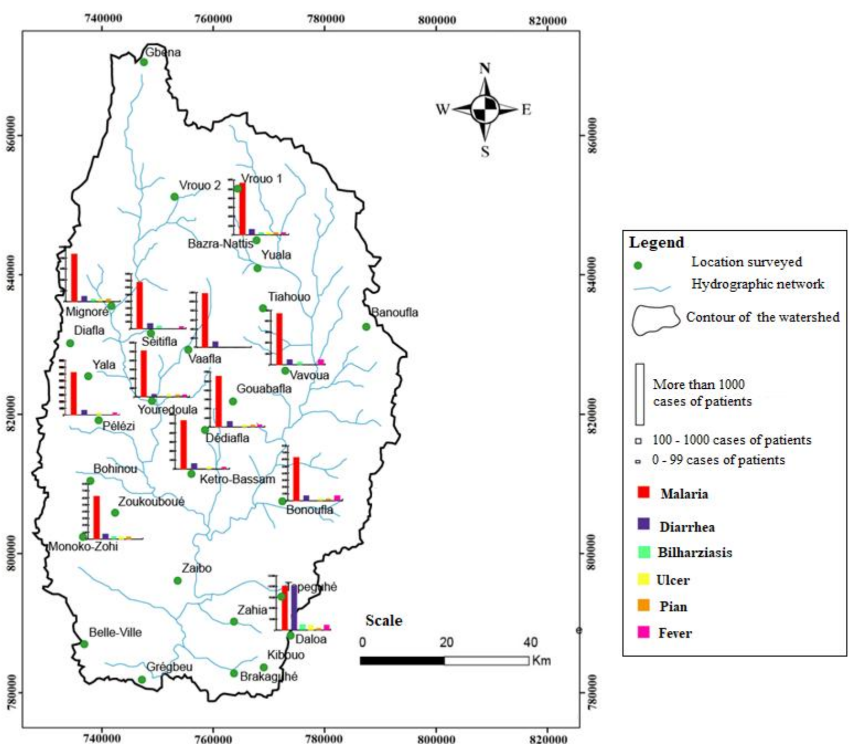

Fig. 10. Map of basin-wide proportions of waterborne disease cases

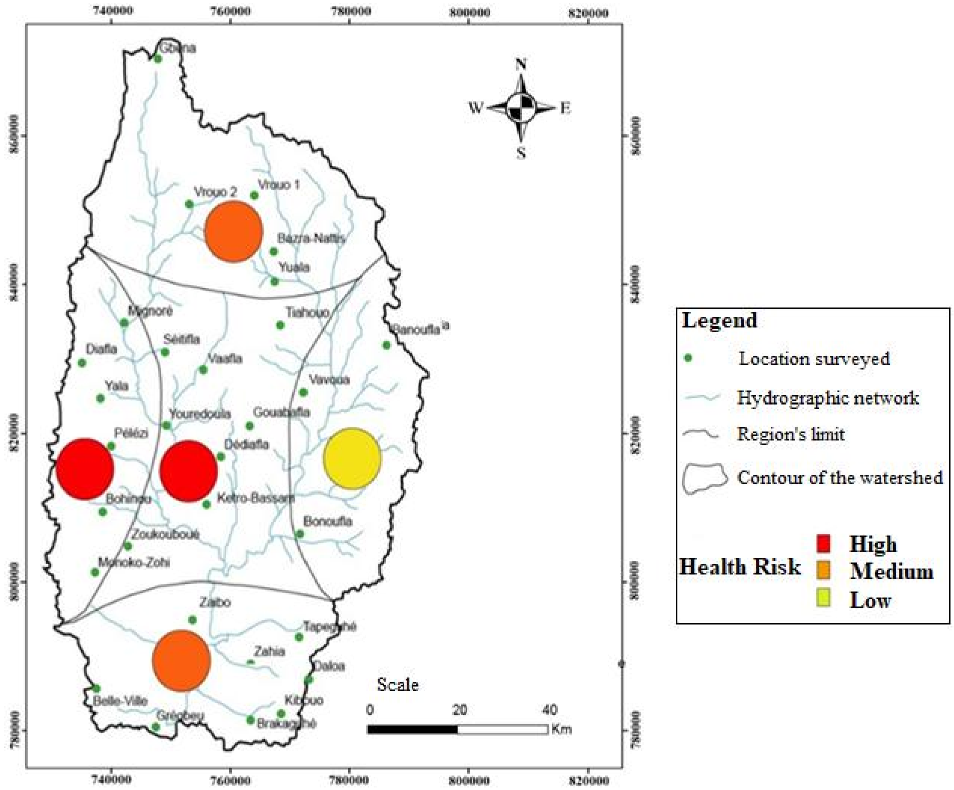

Fig. 11. Map of the spatial distribution of health risks at the basin level

4. CONCLUSION

The nature of the sources of drinking water supply (DWS) in households in the Lobo watershed is linked not only to their standard of living, but also to the weak water distribution network by SODECI. The majority of households in rural and urban areas use well water for their drinking water supply. This water, which is the most consumed throughout the watershed, is associated with health risks. Also, in addition to well water, other sources of water supply have a low level of hygiene and sanitation that contributes significantly to the degradation of water quality. Several factors that can influence water quality have therefore been highlighted. These main factors are the nature and origin of the container, the environment of the container and the standing of the dwelling, the duration of storage, the characterization of the water intake and the transport conditions (container and distance travelled). Given these different indices, both the quality of the water and the health of the population are impacted. These diseases impact the health of populations and this is reflected both in the magnitude and losses generated. The risk of disease is not spared with the behavior of the population towards the use of water. This is felt more in rural than in urban areas, where households do not always respect the rules of hygiene, exposing them to waterborne diseases. Therefore we propose an integrated approach between communities and decision-makers to address the problem of access to safe drinking water in order to mitigate health risks. Thus, it will be necessary to educate the population for a change in behavior.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

ACKNOWLEDGEMENTS

This work was supported by IRD within the framework of the grant to the AMRUGE-CI project entitled "Elaboration of an integrated

water resources management model for the improvement of the drinking water supply of the commune of Daloa (EPEAEP_Daloa)".

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Baechler L. Access to water: A major challenge for sustainable development, Cairn.info for International Center for European Training, French. 2017;36.
2. Dégbey C, Makoutode M, Ouendo EM, Fayomi B, De Brouwer C. The quality of well water in the commune of Abomey-Calavi in Benin. Environnement, Risques & Santé, French.. 2008;7(4):279- 283.
3. Adjiri OA, Assoma TV, Soro G, Aka N, Bengaly I, Soro N. Evaluation of the suitability of natural spring water use in agriculture using hydrochemical techniques: Case of the departments of Daloa and Zoukougbeu, Côte d'Ivoire. Afrique SCIENCE, French. 2020;16(1):204–217.
4. Hounguevou SCG, Tohozin CAB, Soumah M, AttolouSètondji FB. GIS approach for a spatial analysis of hydraulic infrastructures in the commune of Zè, Benin. Journal of Applied Biosciences, French. 2014;(73):5949– 5958.
5. World Health Organization/United Nations Children's Fund (WHO/UNICEF). Water sanitation health. Joint monitoring report: progress on sanitation and drinking water, 2010.
6. Tia L, Seka SG. Private actors and drinking water supply for the populations of the Abobo-Côte d'Ivoire commune. Canadian Journal of Tropical Geography French. 2015;2(2):15-28.
7. Dégbey C, Makoutode M, Fayomi B, De Brouwer C. The quality of drinking water in the workplace at Godomey in 2009 in Benin West Africa. J Int Santé Trav, French. 2010; 1:15-22.
8. World Health Organization (WHO). Malaria Expert Committee. Technical Report Series, Twentieth Report. Geneva, French. 2000;892:85.
9. DSRP. Strategy to revive development and poverty reduction. Republic of Côte d'Ivoire; 2009. French.
10. Koukougnon WG. Urban environment and access to drinking water: The case of Daloa (central-western Côte d'Ivoire), PhD thesis, University of Cocody, Abidjan, IGT, French. 2012;370.
11. Diarra A, Dali GC. Drinking Water Crisis in Urban Areas: Case of the City of Daloa. Review of Geography of the University of Ouagadougou I, Ouagadougou, French. 2016;132-151.
12. Bouyer J, Hénom D, Cordier S, Derriennic F. Quantitative principles and methods. Editions INSERM, Paris, French. 1995;498.
13. Vaughan JP, Morrow RH. Epidemiology manual for health management at the district level. Geneva: WHO, French. 1991.
14. Gomis JS, Thior M. Access to drinking water and sanitation in informal settlements in the commune of Ziguinchor (Senegal): The example of nema 2 and coboda. Larhyss Journal, French. 2020;41:27-46.
15. Mbanmeyh MM, Loundou Messi PB. Informal water trade in the town of Maroua (Cameroon): Economic activity and health risks. Annales de l'Université de Moundou, Series A Faculty of Letters, Arts and Human Sciences, ISSN, French. 2019;6(2):2304-1056.
16. Burkhardt G, Charpentier S, Desille D, Dussaux V, Milin S. Access to drinking water in developing countries: 18 questions for sustainable services, a practical guide for water agencies. Water Agencies, ARENE, AFD. Water Solidarity Program, Paris, France, French. 2012;50.
17. Howard G, Bartram J. Domestic Water Quantity, service level and health, Geneva, WHO. 2003;33.
18. Prost A. Water and health, in Dos Santos S. 2006, Access to water and socio-sanitary issues in Ouagadougou-Burkina Faso, Space, Population, Societies, French. 1996;271-285.
19. Dos Santos ; 2006,
20. Kouakou JGS, Oga S, Claon S, Bama M, Koua DM, Houénou Y. Water access and storage conditions: Household survey in peri-urban areas in Abidjan in 2010. Public Health. 2012;2(24). 2012;133-142.
21. Kombassere A. Access to drinking water and diarrheal risks in the irregular areas of Ouagadougou: The case of Yamtenga, Master's thesis, University of Ouagadougou, French. 2007.

Available:http://www.memoireonline.com/07/09/2242.

22. Jemmali H, Amara M. Mapping and Multivariate Spatial Analysis of International Water Poverty. In the 3 rd Euro-African Conference on Finance and Economy (CEAFE), Paris, French. 2010;18.
23. M'bra Kouassi R, Kone B, Kouakou YE, Silue B, Cisse G, Soro N. Drinking water supply, quality of the resource and associated health risks at Korhogo (North Côte d'Ivoire). Environmental Health Risk. 2015; 14:230-241. French DOI: 10.1684/ers.2015.0781
24. Ngnikam E, Mougoue B, Tietche F. Water, Sanitation and Health Impact: A Case Study of an Urban Ecosystem in Yaoundé. Proceedings of the JSIRAUF, Hanoi, French. 2007;6-9.
25. Gnazale GGR. Contribution of geomatics to the analysis and modeling of the impact of climatic and environmental factors on the proliferation of schistosomes in Ivory Coast: Case of urinary schistosomiasis in the Belier region and Yamoussoukro district. Félix Houphouët Boigny University, CURAT, French. PhD thesis. 2020;166.
26. Tran A. Remote Sensing and Epidemiology: Modeling of insect population dynamics and application to the control of vector-borne diseases. PhD thesis, University Louis Pasteur Strasbourg, French. 2004;1: 218.
27. Kouame AKD. Distribution factors and test modelling of bilharziasis and geohelminthiasis by remote sensing and geographic information system techniques for sustainable development in the Agnéby region. Felix Houphouët Boigny University of Abidjan, French. PhD thesis. 2010;144.
28. N'dri F. Contribution of GIS in the epidemiological surveillance of cholera: Cases in seven precarious neighborhoods in the city of Abidjan (southern Côte d'Ivoire) French. Research Master's thesis, Félix Houphouet Boigny University of Abidjan-Cocody. 2014;79.
29. Ramanantsizehena P, Ramiranirina B. Health risks: Epidemiology, Geographic Information System and Remote Sensing: The case of bilharziasis in Schistosoma mansoni in the sub-prefecture of Manandriana, Madagascar. 10th Scientific Days of the AUF Remote Sensing Network, Geohazards and Remote Sensing Ottawa, Canada, French. 24 - 29 mai. 2004;125-135.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/63767