

Health Impact of Flooding in the Town of Aboisso in Southeastern Côte d'Ivoire

Kalitia Fatoumata Sekongo^{1,*} and Sophie Pulchérie Tape²

ABSTRACT

One of the most widespread climatic effects in Africa is flooding. Generally caused by high rainfall, overflowing rivers, relatively flat sites, and proximity to the water table, they are amplified by numerous anthropogenic factors. This is the case of the town of Aboisso, which has been experiencing flooding since 2018. However, the recurrence of this phenomenon of hydric origin, with its corollaries of availability and proliferation of pathogens, is a concern for the population. Indeed, wastewater overflows caused by flooding increase the risk of infectious diseases. The aim of the present study is, therefore, to analyze the health impact of flooding due to climatic and anthropogenic factors in Aboisso. The methodological approach consisted of documentary research, field surveys, and direct observation. Several software programs were used to process the data. The analysis method used is the deductive approach. The results showed that the determinants of flooding in Aboisso are hydro-climatic and anthropogenic. The most recurrent pathologies in Aboisso, especially during periods of heavy flooding, are malaria (59%), acute respiratory infections (21%), anemia, which was the main cause of death in 2020 and 2021 (15%), and diarrheal diseases (5%). Finally, a number of resilience strategies (or actions to be taken to strengthen resilience to flood-related health risks in Aboisso were proposed) to flood-related health risks in Aboisso were proposed.

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¹ Doctoral Student, Peleforo Gon Coulibaly University, Côte d'Ivoire.

² Teacher-Researcher, Peleforo Gon Coulibaly University, Côte d'Ivoire.

* Corresponding Author:
e-mail: kalitiasekongo@gmail.com

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1. INTRODUCTION

The world's growing population is putting considerable pressure on planet Earth. It is thus confronted with intense human activity. Indeed, the 7.3 billion people in the world today [1] are contributing to poorly controlled urbanization, increasingly generating needs in terms of decent housing, access to drinking water, sanitation, and healthcare [2]. What's more, with an estimated world population of 8.5 billion in 2030, again according to the Unwto [1], societies, by perpetually modifying their environment, which can be analyzed as a dynamic between an environment and a population, are creating conditions favorable to the disappearance of natural ecosystems, and to the entrenchment and emergence of certain ailments. In addition to the modification and/or degradation of the living environment by societies themselves, there are factors beyond man's control, such as floods resulting from the effects of climatic variability. According to Tanguy [3], floods alone accounted for 43% of disasters recorded

worldwide during the period from January 2001 to December 2015. In West African countries, populations fall victim to floods every year [4]. Indeed, the phenomenon of climate change is at the root of rising waters, submerged land, rising temperatures, and increased health risks [2]. The city of Aboisso is not immune to this climatic reality. Located in southeastern Côte d'Ivoire, this capital of the Sud-Comoé region has been facing waves of flooding since 2018. This hydric agent, combined with the poor management of household waste, contributes to the insalubrity of the study area, making it, in turn, a potential breeding ground for pathogens [5]. What, then, is the impact of such an environment on the spatial distribution of pathologies in Aboisso? The present study aims to analyze the impact of environmental factors on the spatial distribution of diseases in Aboisso. The aim was to identify the environmental and anthropogenic determinants, analyze the diseases and their spatial distribution, and propose some resilience strategies.



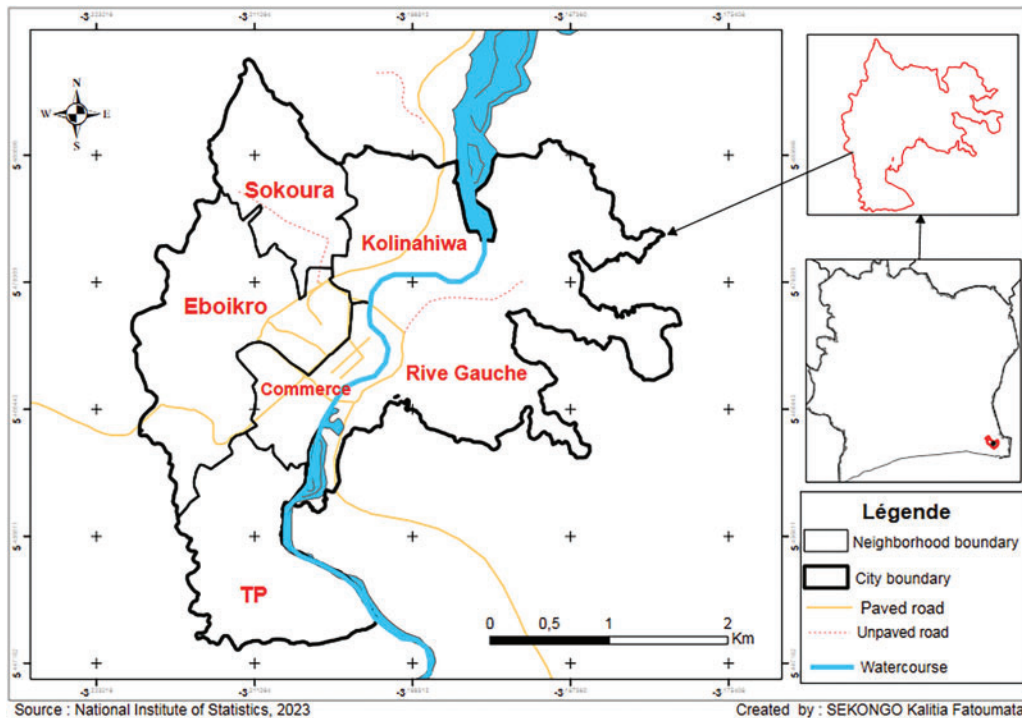


Fig. 1. Geographical location of the town of Aboisso.

2. DATA AND METHODS

The methodological approach of our study was based on quantitative and qualitative data collection methods. Data collection began with the creation of a documentary database. Specifically, this involved consulting and analyzing thematic books and technical reports from SODEXAM from 2018 to 2022; medical reports from the city's main health centers, notably the Centre Hospitalier Régional (CHR), Protection Maternelle et Infantile (PMI), Service de Santé Scolaire et Universitaire (SSSU) and medical clinics (Source de vie, Sainte Famille and Sanwi); and epidemiological data from 2020 to 2023. The information gathered was used to analyze rainfall trends and identify the pathologies to which populations are exposed. The field surveys carried out in November and December 2023 involved interviews with local administrative and municipal authorities, and questionnaires were administered to a sample of 100 household heads using quotas and purposive methods. The selection was based on simple criteria, notably length of time in the town, age, and socio-professional status (Table 1). In addition, the city has 19 sub-neighborhoods grouped into six major districts (Fig. 1). The number of households to be surveyed per district was proportional to the household size of each district. The questionnaire covered waste management, annual changes in rainwater levels, flooding of at-risk sites, and related illnesses. To process the data collected, we used Excel 2013 to create the statistical tables, sphinx 4.5 to design the questionnaires, and Q GIS version 3.12 to create the maps. The results were analyzed using an empirical-inductive approach.

3. RESULTS

3.1. Determinants of Flooding in Aboisso

3.1.1. Aboisso, A Well-Drained Urban Site

Located in the southeast of the Ivory Coast, the urban site of Aboisso is divided into two banks by the coastal river Bia. This river rises in Ghana, where 2/3 of its 300 km course is located and flows into the Atlantic Ocean via the Aby lagoon. The town is also located downstream from 02 hydroelectric dams, Ayamé 1 and Ayamé 2, which hold a volume of water of close to one billion m^3 . In addition, this locality has inherited a rugged relief, alternating high hills and valleys marked by numerous streams. Its rugged terrain and the presence of numerous bodies of water make the study area vulnerable to flooding. Aboisso is therefore affected by flooding of the River Bia during the rainy season and/or by the discharge of water from dams (Figs. 2 and 3). In fact, according to the deputy manager of the Ayamé 1 and 2 plants, the dams often reach the limit of their storage capacity. In such cases, the dams are opened to evacuate the excess water. The neighborhoods most affected by flooding are TP, trade and left bank.

3.1.2. Abundant Precipitation

Another determinant of flooding in Aboisso is the abundance of rainfall. Indeed, one of the impacts of climate change is the intensification of certain rainfall events. A rainy day is one on which at least 1 mm of water accumulates. The period with the most precipitation lasts eight months, from March 10 to November 11 (Fig. 2). The wettest month is June, with an average of 293 mm, followed by May and October. Rainfall averages around 1500 mm per year. However, over the period 2018 to 2022, average rainfall rose from 1500 to 1866.51 mm. Aboisso is therefore an area with high rainfall, which since 2018 has been the

TABLE I: NUMBER OF HOUSEHOLDS SURVEYED BY NEIGHBORHOOD

Neighborhoods	Household size	Number of households surveyed
Trade (Commerce)	1008	12
Eboikro	1388	16
Koliahiwa	723	8
Sokoura	1558	18
TP	1125	14
Left bank (Rive gauche)	2788	32
Total	8590	100

Source: Our surveys, 2023.

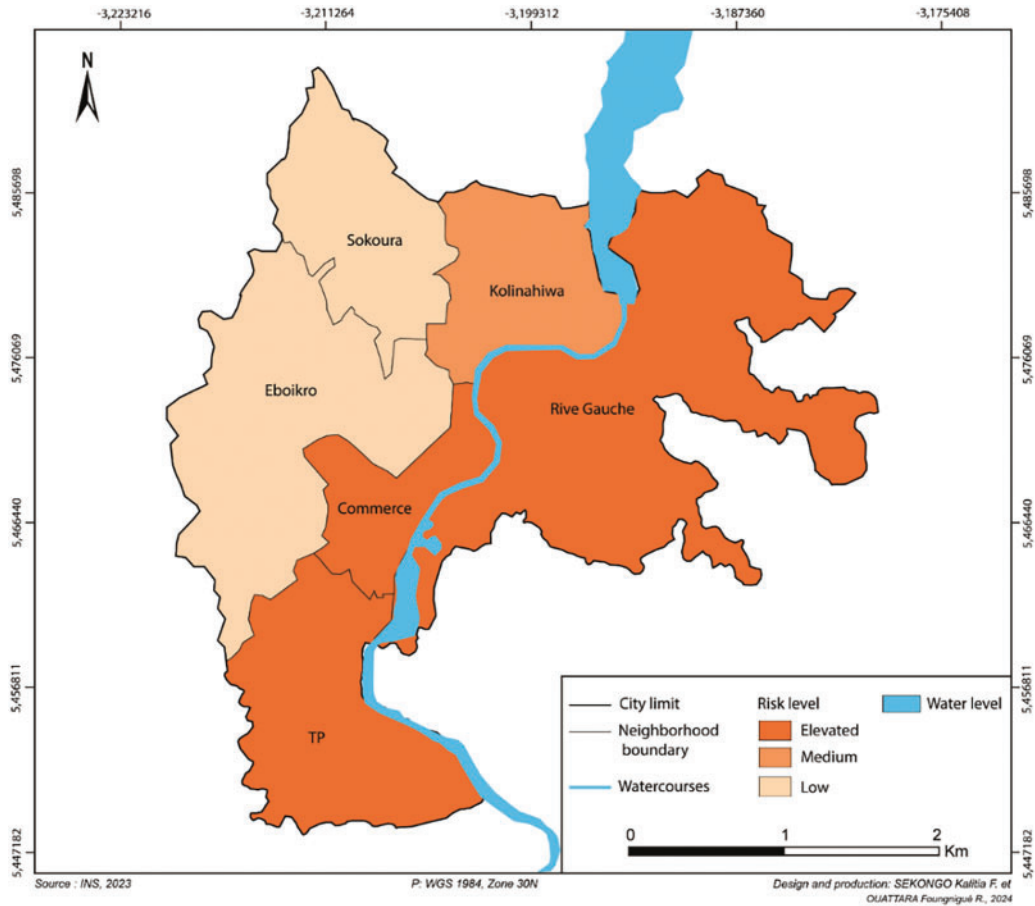


Fig. 2. Map of flood risk in the town of Aboisso.



Fig. 3. Flooding in the left bank district (Rive gauche) (a) and TP districts in 2023 (b). These neighborhoods are among the most flood-prone in the city. Source: Our surveys, regular.

reason for flooding of the River Bia, which in turn causes flooding.

Fig. 4 shows two rainy seasons and two dry seasons. The longest rainy season extends from April to July, with a peak in June (293.21 mm). The average rainfall volume from

2018 to 2022 is 1866.51 mm, demonstrating the frequency of rainfall. Rainfall has also been increasing over the years. In 2018, for example, the city recorded 1645.31 mm of rain; in 2019, 1761.33 mm; in 2020, 1777.15 mm; and in 2021 and 2022, 2031.3 mm and 2117.5 mm, respectively. Rainfall is, therefore, constantly changing.

3.2. Health Risk Factors in Aboisso

3.2.1. The Presence of Stormwater Basins

The town of Aboisso is home to two stormwater basins in the TP district (Fig. 5). These are nauseating stagnant waters that are greenish in color and contain waste. This water is present all year round and is exacerbated during the rainy and extreme rainy seasons, contributing to the flooding of homes in these neighborhoods. It is also a potential reservoir of malaria pathogens, as it is covered in mosquitoes. In addition to making the neighborhood unhealthy, the areas around these basins constitute a

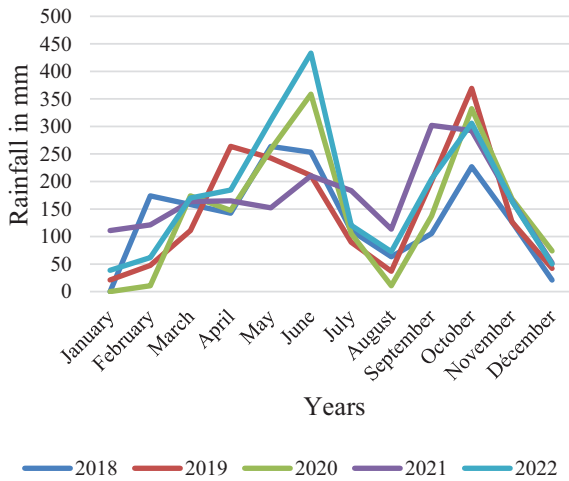


Fig. 4. Rainfall trends in Aboisso from 2018 to 2022. Source: Sodexam data 2018, 2019, 2020, 2021, 2022.



Fig. 5. View of the stormwater basins in the TP (a) and Trade districts (b). Source: Our surveys, 2023.

TABLE II: DISTRIBUTION OF NEIGHBORHOODS BY FLOOD RISK LEVEL

Neighborhoods	Risk level
Left bank, Trade, TP	Very high
Koliahiwa,	Medium
Sokoura, Eboikro	Low

Source: Our surveys, 2023.

dumping ground for household waste and a defecation site that is irregularly cleaned and poorly maintained.

These stormwater basins in the middle of the city are breeding grounds for mosquitoes and flies.

Meteorological hazards have always been part of everyday life in Aboisso. However, with the effects of climate change, these once rare phenomena are tending to amplify, affecting several spatial units to varying degrees (Table II).

According to Table II, the neighborhoods most affected by this natural flooding disaster are Rive Gauche, Commerce, and Travaux publics because of their proximity to the River Bia. When it rains, these neighborhoods are the most vulnerable. In addition, when the Ayamé dams are opened to evacuate excess water, the level of the Bia rises considerably, with flooding consequences for nearby neighborhoods. It should also be noted that other neighborhoods are at risk of flooding due to the presence of the River Bia, which flows through the entire town.

3.2.2. Environmental Degradation, A Health Risk Factor

Aboisso’s population is growing faster than ever. From 27,218 inhabitants in 1998, the communal population rose to 63,332 in 2014. Aboisso is home to more than 68% of this communal population, or 43,282 inhabitants [6].



Fig. 6. View of unauthorized garbage dumps near the market in the Trade (Commerce) district. Source: Our surveys, 2023.

Furthermore, the Commerce and Sokoura districts have the highest population density, with 89 hab/ha and 74 hab/ha, respectively. The other neighborhoods, notably Eboikro (41 hab/ha), Koliahiwa (39 hab/ha), and Travaux publics (38 hab/ha), come in second. The Left Bank district accounts for 72.46% of the city’s population but has a density of 36 inh/ha. This district is the largest spatially. All these demographic parameters point to strong population growth, leading to increased waste production.

The scale of household waste production and its poor management are transforming the urban landscape of Aboisso into an unhealthy place characterized by widespread visual nuisance. According to the national average household waste production classification, one inhabitant in one day in Côte d’Ivoire produces 32,461.2 kg [7]. However, in Aboisso, the household waste collection rate is around 29% [7]. As a result, the population lives with nearly 71% of this domestic waste. It should be noted that around 75% of respondents admit to dumping their household waste in open-air refuse dumps not far from their homes, especially in the Eboikro and Sokoura districts, where there are 16 and 8 open-air refuse dumps, respectively. Some of the latter admitted that, during heavy rains, they dump their waste directly into run-off water. 15% of those surveyed said that they used pre-collectors, and only 5% said that their garbage was collected by the town hall, but that this service was not regular. We are, therefore, witnessing a proliferation of unsanitary sites in the city’s various districts, constituting a source of pathogen exposure for mosquitoes and midges (Fig. 6). In addition, the banks of the River Bia are used by local residents as a dumping ground for waste of all kinds. This constant dumping of waste in the streets and gutters is degrading the banks of the Bia.

Fig. 6 shows one aspect of the way in which people are contributing to the process of environmental degradation. Demographic pressure and poor management of household waste have led to an accumulation of used objects that escape collection, litter the streets, and clog the gutters.

3.3. The Health Impact of Flooding in Aboisso

3.3.1. Identification of Pathologies Present in the City of Aboisso

The deterioration in living conditions associated with flooding is affecting the health of the population of Aboisso. The multiplicity of pathogens increases the population’s vulnerability to water-borne diseases. The city of Aboisso is characterized by four main pathologies:

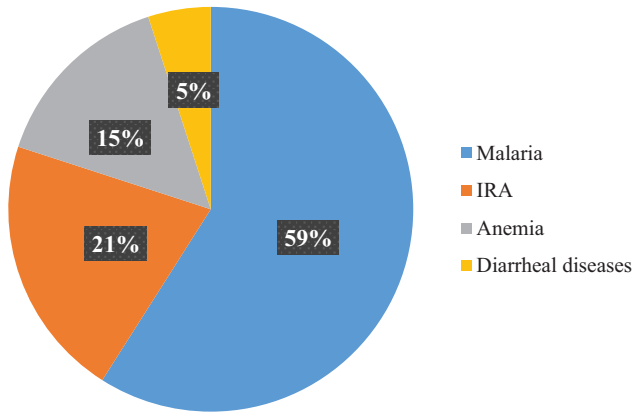


Fig. 7. Proportion of most recurrent pathologies in Aboisso. Source : DDSHP Aboisso, 2023.

malaria, acute respiratory infections, anemia, and diarrheal diseases, as shown in Fig. 2. In fact, after processing the epidemiological data collected, malaria is the condition in the first place. It accounted for 59% of consultations for all pathologies in the city during the period 2020–2023 and continues to grow steadily. This situation is indicative of the deep-rootedness of pathogens in the study area. This fact attests to the favorable conditions that contribute to the multiplication of transmission vectors mentioned above. Pathologies such as bronchitis and anemia account for 15% of ailments. Although anemia is not described as a pathology but rather as a symptom of a severe form of malaria, its progression could find an answer in the entrenchment of malaria vectors in the study area.

Fig. 7 shows that malaria (59%) and other diseases predominate among the Aboisso population, notably acute respiratory infections (21%), anemia (15%), and diarrheal diseases. These diseases are a major health concern, as they are under surveillance. The presence of these waterborne pathologies is the consequence of the combination of flooding and increasing insalubrity in the city. Thus, if we relate rainfall to the city’s dominant pathologies, we realize that the period from May to July 2021 accounts for just over a third of consultations linked to malaria (1352) and respiratory infections (470).

3.3.2. The Spatial Distribution of Pathologies in Aboisso

Fig. 8 shows the predominant pathologies for each district. These unevenly distributed pathologies are based on the criterion of the average number of consultations per disease and per district from 2020 to 2023 at the various health centers.

The area with the highest prevalence of malaria and acute respiratory infections is the Rive Gauche district, with 70% of consultations, followed by the TP district, with 67%, and the Commerce and Koliahiwa spatial units, with 65%. This situation is explained by the fact that these neighborhoods are the most exposed to and affected by flooding (Table III). As a result, puddles and pools of water become extensive breeding grounds for pathogens. Also, the presence of depressed areas, the proximity of forest cover, the presence of scrub in the middle of town and unfinished housing in this changing environment, during the rainy seasons, become zones of

microbial and parasitic proliferation, thus sustaining the vectors of pathogenic germs.

These neighborhoods are also the hardest hit by acute respiratory infections. This is due not only to repeated flooding but, above all, to the permanent presence of the Bia coastal river near these neighborhoods.

There is also a low rate of anemia in these areas. Anemia is not a pathology in itself but rather the result of a severe form of malaria. The low rate of anemia in these neighborhoods can be explained by the rapid access to health services for consultations. Indeed, as soon as the first symptoms appear, they rush to the health centers to receive the appropriate care. This eagerness and good health reflex reduces the occurrence of severe forms of malaria in these areas. There are three health centers in the commercial district alone: the PMI and the Sainte Famille and Sanwi medical clinics.

Diarrhoeal diseases are virtually non-existent in Rive gauche, Commerce, and Travaux publics (TP). In Koliahiwa, diarrhoeal diseases account for 5% of consultations in the district. This is due to the fact that Koliahiwa is one of the city’s most insalubrious districts, with more than eight unauthorized garbage dumps and numerous open-air toilets.

Areas with a high prevalence of anemia and diarrheal diseases are the neighborhoods concerned Eboikro and Sokoura. These neighborhoods respectively account for 30% and 37% of consultations due to anemia and 11% and 10% of consultations due to diarrheal diseases. This situation can be explained by the fact that these neighborhoods are among the most insalubrious in the city. In fact, Eboikro has 16 open-air dumps and open-air toilets, and Sokoura has 8. This insalubrity, combined with flooding, leads to numerous health risks, notably anemia. Although anemia is not described as a pathology but rather as a symptom of a severe form of malaria, its progression could find an answer in the entrenchment of malaria vectors in the area. Over 80% of those surveyed in these two districts claimed to have contracted malaria at least once during the year. However, over 65% of those surveyed admitted to using traditional medicines, and only going to the health center when the condition became serious. According to epidemiological data, almost 45% of malaria cases in these neighborhoods are severe cases. This practice explains the high rate of anemia, as well as diarrheal diseases.

Table IV shows that the TP, Left Bank, and Koliahiwa districts have no functional health centers. However, these are the districts with the highest number of malaria cases. As for the Eboikro and Sokoua districts, which have two and one health center, respectively, these populations are the ones recording the most cases of anemia due to the neglect of malaria cases.

4. DISCUSSION

Natural disasters are extreme weather events that affect a large number of major and secondary cities in all countries of the sub-region [8]. According to WHO [9], flooding can indirectly contribute to the increase in vector-borne diseases, as it promotes the multiplication and widening of the range of vector habitats. These results show that

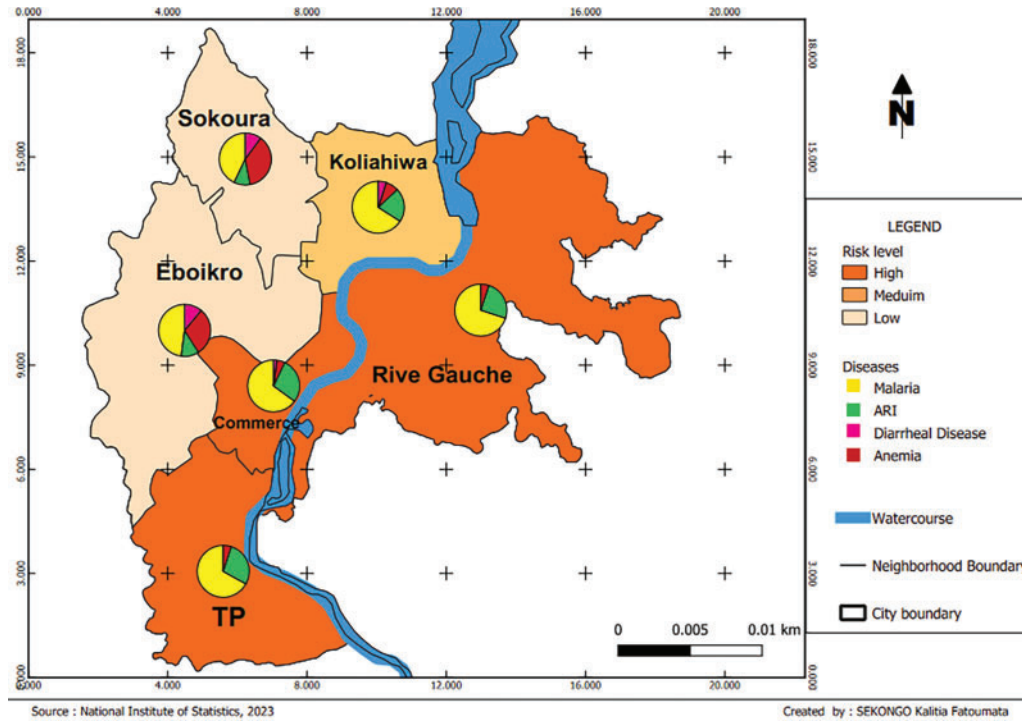


Fig. 8. Level of risk and distribution of pathologies in the town of Aboisso.

TABLE III: ASSESSMENT OF THE LEVEL OF HEALTH RISK IN ABOISSO

Level disease prévalence	Neighborhood	Flooding	Forest proximity	Depression zone	Urban planning problems
High prevalence Malaria	Left bank	+++	+++	++	+++
	TP	+++	+	++	++
	Trade	+++	+	+++	+++
Average prevalence	Koliahiwa	++	+++	++	+++
Low prevalence	Sokoura	+	++	+++	+++
	Eboikro	+	++	++	+++

Note: Increased phenomenon = +++; Medium Phenomenon = ++; Weak Phénoménon = +.

TABLE IV: NUMBER OF HEALTH CENTERS PER DISTRICT

Districts	Number of health centers
Trade	03
Eboikro	02
Koliahiwa	-
Sokoura	01
TP	-
Left bank	-
Total	06

Source: Our surveys, 2023.

Aboisso is a locality prone to flooding. As a result, it is an area prone to pathologies linked to flooding and insalubrity. Indeed, the study showed that malaria, acute respiratory infections, anemia, and diarrheal diseases are the dominant pathologies in Aboisso. This work concurs with that of Tape and Konan [2], who, in his analysis, asserted that these results were also perceptible in Adiaké. Niamke [10] and N'takpe and Alla [7] believe that environmental degradation is the explanatory factor for the pathologies developed by the people of Aboisso. In Aboisso, the soil is a ferralitic type with low permeability, which slows down the infiltration of rainwater. These results were reported by [11] in Tiassalé. This type of soil

retains water on the surface in neighborhoods and even in residential yards, creating breeding grounds for larvae. The town's sanitation system is also deficient. In fact, the lack of public works to drain runoff water leads to flooding in neighborhoods during the rainy season, resulting in the formation of gullies and crevasses. Water stagnating in these places becomes a breeding ground for malaria pathogens. Household wastewater in Aboisso is discharged into streets, gutters, cesspools, and vacant lots. This water, constantly exposed to the sun, becomes a potential breeding ground for malaria, regardless of the rainy season. According to Houessinon [12], the main adaptation and mitigation strategies used by populations are backfilling and raising foundations. The results of a study carried out in rural areas indicate that, in the face of the hazard, communities move to host families [13].

5. CONCLUSION AND RESILIENCE STRATEGIES

The town of Aboisso is exposed to the risk of flooding. This situation is the result of a number of factors, both environmental and man-made, in particular its geographical location, the abundance of rainfall, and the obstruction

of drainage channels due to poor management of household waste. The recurrent flooding recorded in the locality has health repercussions for the people of Aboisso. Flood-related pathologies in Aboisso are dominated by malaria and acute respiratory infections. Severe malaria was the main cause of natural deaths, with 20 and 23 deaths, respectively, recorded in 2019 and 2020. However, despite having a lower percentage of consultations (15%), anemia resulting from severe forms of malaria was the main cause of death in 2021. Actions such as cleaning drainage channels to allow rainwater to drain away, collecting household waste, and permanently relocating populations from at-risk areas are many strategies for limiting the consequences of flooding in the city of Aboisso.

CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

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