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## Chapter

# The Challenge of Water in the Sanitary Conditions of the Populations Living in the Slums of Port-au-Prince: The Case of Canaan

*Yolette Jérôme, Magline Alexis, David Telcy, Pascal Saffache and Evens Emmanuel*

## Abstract

Haitian cities are more and more prone to demographic growth, which has a lasting effect on water distribution infrastructures, as well as those that make it possible to clean it up. They are in touch with the growing demand for water, but also with the management methods of this resource. Over the past 25 years, the enlarged agglomeration of Port-au-Prince, the largest agglomeration in the country, has experienced very strong urban expansion with the creation of new precarious spaces. The literature reports that Haiti is now more than 64% urban and 35% of its population lives in the metropolitan area of Port-au-Prince, in the West Department. Over the past decade, the footprint of the Port-au-Prince metropolitan area has grown by 35%. Recent observations on the formation and development of some slums highlight the country's vulnerability to land-based hazards, which support this form of urbanization through the emergence of environmental displaced persons. Canaan, a human settlement created following the earthquake of January 12, 2010 by presidential decree, and inhabited by the victims of this event, has a deficit in infrastructure and basic urban services. The results of our previous work on this territory lead to a much more in-depth reflection on the need to develop an index of vulnerability to environmental diseases for the population. In fact, most of the households that live there face very precarious situations. The health conditions associated with this context expose the population to increased risks of disease. The measures taken by families to treat water at home do not seem to limit their vulnerability to environmental diseases (infectious and chronic). Improving living conditions in Canaan with a view to sustainability therefore underlies major challenges. What avenues of intervention should be favored to facilitate a favorable development of the population, while taking into account the strong constraints that weigh on their daily lives? The objective of this study is precisely to analyze the vulnerability of the population to water-borne diseases.

**Keywords:** slums, vulnerability index, urban precariousness, water and sanitation quality, overpopulation, Canaan

## **1. Introduction**

Ensuring a quality water supply to human communities in the North and South is an ongoing process [1]. Indeed, water is essential for sustaining life and a satisfactory supply of drinking water must be made available to all consumers [2]. According to the WHO (2003) [3], 80% of illnesses and deaths among children worldwide are due to unsafe drinking water. Kosek et al. [4] note that between 1992 and 2000, 2.5 million annual deaths in children under five were due to diarrhea. The main component of this disease burden being linked to water [5].

For more than four decades, the issue of access to water in quantity and quality has never ceased to be raised worldwide. The United Nations, academic institutions, NGOs and governments have shown, through the organization of several international conferences, their interest in the global crisis caused by the mismatch between available resources and the increase in human, economic and environmental, as well as pollution due to human actions and global changes. Indeed, the first international conference on water, held in Mar del Plata (Argentina) from March 14 to 25, 1977, had a major impact on dialog at the global level and on the development of United Nations programs. It led to the International Drinking Water Supply and Sanitation Decade (1981–1990), which, among other things, aimed to reduce the incidence of water-related diseases.

Many international events and initiatives have followed one another on the issue of water - a determinant of health - since the Mar del Plata conference in 1977, sometimes under the aegis of the United Nations, sometimes under that of international financial institutions, but also within the framework of ad hoc forums where multinationals and their supporters played a preponderant role [6]. In January 1992, the International Conference on Water and the Environment in Dublin made an alarming observation: the world water situation is in danger, fresh water is scarce and its use must be done with consideration [7]. This observation was taken up at the Rio Earth Summit in 1992 and was the subject of chapter 18 of Agenda 21 established at the time (“Protection of freshwater resources and their quality: application of integrated approaches to in value, management and use of water resources”).

The adoption of the Millennium Development Goals (MDGs) from the United Nations Millennium Declaration [8] embraced a vision of the world in which developed and developing countries would fight together against poverty. At the signing of the said declaration, the number of people without access to safe drinking water and improved sanitation facilities around the world was alarming: 1.1 (or 17% of the world population) and 2.4 billion, respectively [9]. The majority reside in precarious neighborhoods, especially in countries without running water and adequate sanitation systems, and mainly use traditional methods for their provision [10–12].

Among the MDG goals, target 7 (c) aimed to halve, by 2015, the percentage of the population without access to safe drinking water and basic sanitation services. [13] report that in 2010, the global MDG target for drinking water was reached in 2010. According to this report [13]: (i) 91% of the world population used 2010 improved water point; (ii) 96% of the world’s urban population uses improved water points compared to 84% in rural areas; (iii) in 2015, 663 million people still do not have access to water points. Improved water supply; (iv) 2.4 billion people still do not have improved sanitation facilities.

The PNUD [14] reports “beyond the issue of water supply for personal and domestic use, the lack of safe water and sanitation infrastructure is also a leading causes of poverty and malnutrition, and insecure water supplies linked to climate change threaten to increase the number of people affected by malnutrition, which is

expected to reach between 75 and 125 million by 2080”. This analysis is of particular concern to the human settlement of CANAAN. This slum constitutes in itself a particular epidemiological environment, where the absence of collective collection of solid waste, of drainage of domestic wastewater and the consumption of water of non-guaranteed quality promotes the circulation of pathogenic germs which constitute risk factors for the health of the population and the environment [15]. The objective of this study is to study the challenge of water in the daily sanitary conditions of the populations living in the slums of Canaan. This work revolves around two main axes: (i) firstly, urbanization and sanitary conditions (water, sanitation and hygiene) in the slums of Port-au-Prince are addressed; (ii) the second axis traces the history of Canaan, a shanty town built in a drought-stricken area.

## 2. The sanitary conditions of the slums of Port-au-Prince in the face of morbidity due to water, sanitation and hygiene

### 2.1 Urban socio-spatial organization of Port-au-Prince

Port-au-Prince is the political and economic capital of the Republic of Haiti. It is, according to Millian and Tamru [16], “a town founded on an exceptional site, between sea and hill: the bay of Gonâve and the foothills of the Selle chain, surrounded by two fertile agricultural plains, that of Cul-de-sac and that of Léogâne. The map of the Republic of Haiti is presented in **Figure 1**. Despite these favorable geographical conditions, the city suffers from a degraded environment: few green spaces, urbanization of the hillsides, polluted coastline occupied by unsanitary neighborhoods, poor quality of the building, generalization of precarious housing”. Port-au-Prince testified and still testifies today to the symptom of urban macrocephaly which characterizes certain under-urbanized countries. In the Haitian

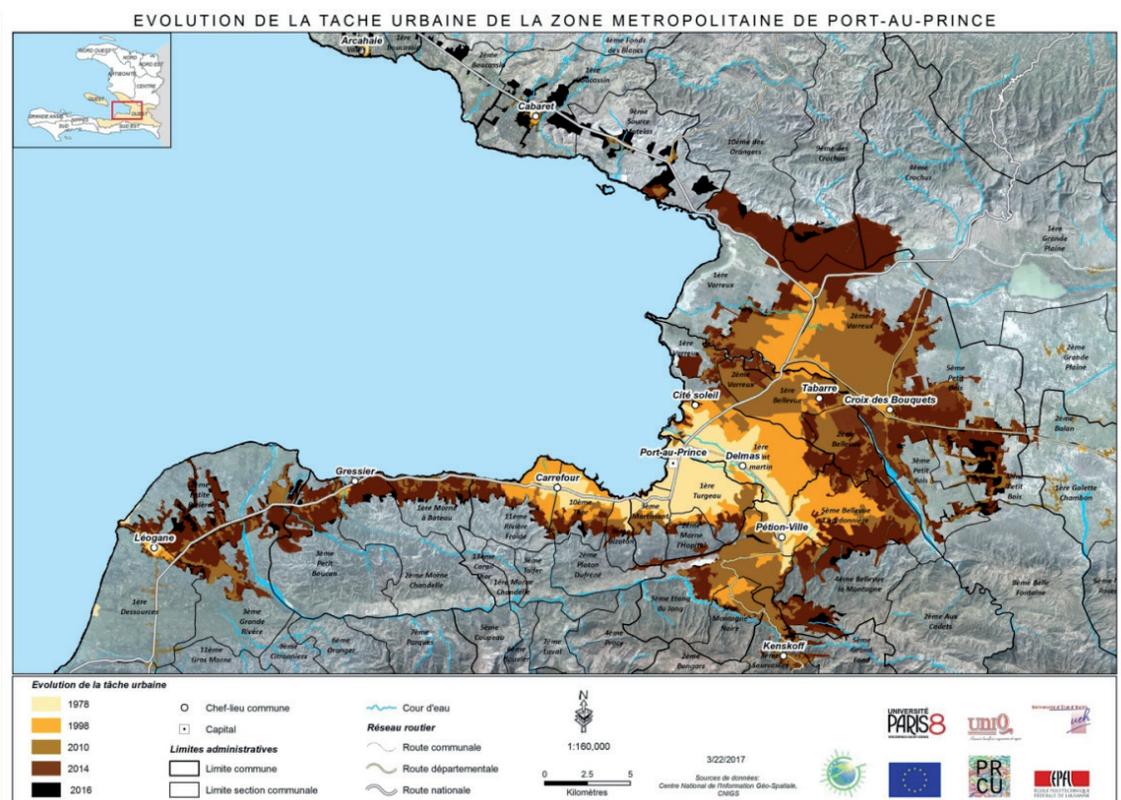


**Figure 1.**  
Map of the Republic of Haiti - (map: Reprinting with permission of CNIGS-Haiti).

universe, this city has long been seen as an island of urban civilization, in a largely rural space [17]. There was Port-au-Prince and there was, as Barthélémy [18] put it, “the land outside”.

Between 1950 and 1982, the population of the city of Port-au-Prince increased from 143,534 inhabitants to 719,517 inhabitants [18]. In fact, in order to attract foreign capital and promote the establishment of subcontracting industries, the Haitian State began during the second half of the decade 1970–1980, a process of liberalization of the economy [19]. Centralized largely in the Metropolitan Region of Port-au-Prince (RMPP), this process has, among other things, led to a significant displacement of the country’s rural population to the urban space of Port-au-Prince [20]. If the census metropolitan area includes the following six cities: Port-au-Prince, Delmas, Cité Soleil, Tabarre, Carrefour and Pétion-Ville, public urban planning bodies speak more of eight Communes (adding Kenscoff and Croix- des-Bouquets to the previous six), when they deal with the metropolitan area of Port-au-Prince [21]. In 2015, the city’s population was estimated at 987,310 inhabitants, with the metropolitan area estimated at 2,618,894 inhabitants [22]. At the turn of the new millennium, the Haitian capital spread out in all directions, without a comprehensive development policy, and its inhabitants are mostly poor or impoverished (workers and soldiers made redundant, pensioners without means) [16]. The evolution of the urban task of Port-au-Prince between 1980 and 2016 is presented in **Figure 2**.

The great attractiveness of the capital for rural populations causes deep urban changes (unprecedented spatial extension, densification and degradation of the existing urban fabric) and an aggravation of the problems facing the Haitian metropolis [23]. The socio-spatial modifications characterizing the urban organization of precarious neighborhoods in Port-au-Prince can be summed up perfectly in the definition of the five levels or dimensions of precariousness in the slums:



**Figure 2.** The evolution of the urban task of Port-au-Prince between 1980 and 2016 [16] - (map: Reprinting with permission of authors).

“(i) physical precariousness, which highlights the environmental dangers due to the very location of the neighborhoods (presence of ravines, swamps, rubbish, etc. (ii) environmental precariousness, which results from the absence of basic services (drinking water, sanitation, elimination of excreta) and the resulting health risks. (iii) land insecurity, which highlights the invasion of land by populations who are not legally the owners. (iv) economic insecurity, because the level of poverty is generally very high. (v) social precariousness, insofar as the inhabitants of precarious neighborhoods are hardly recognized by the public authorities” [24].

## **2.2 Sustainable access to safe water supply and basic sanitation services**

In the joint WHO/UNICEF [13] water and sanitation monitoring program, safe drinking water and basic sanitation are defined as follows: (a) drinking water means water used for domestic purposes, drinking, cooking and personal hygiene; (b) access to drinking water means that the source is located less than one kilometer from the place of its use and that it is possible to obtain regularly at least 20 liters of water per inhabitant and per day; (c) drinking water is water with microbial, chemical and physical characteristics that meet WHO guidelines or national standards for the quality of drinking water; (d) access to drinking water is indicated by the proportion of people using improved drinking water sources: home connection; public standpipes; sounding holes; protected wells; protected sources; rainwater; and (e) basic sanitation is the least expensive technology that ensures hygienic disposal of black and gray water, as well as a clean and healthy living environment both at home and in the vicinity of users. Access to basic sanitation services includes safety and privacy in the use of these services. The coverage shows the proportion of people using improved sanitation services: connection to a public sewer; connection to a septic tank; flush latrine; simple pit latrine; improved latrine with self-ventilated pit.

## **2.3 Access to water in the slums and the prevalence of water-borne diseases in Port-au-Prince**

Dynamic, regional and global pressures, such as climate change, population growth and the degradation of urban infrastructure that cities are undergoing today, are causing water scarcity, making it difficult to manage water effectively. Resource [25]. This situation deprives the populations of the slums of this vital element. The increase in demand for water and the increase in pollution of aquatic ecosystems - two situations resulting from accelerated urbanization - make regional disparities, as well as socio-spatial inequalities more and more visible [26] and make access to water one of the major challenges for humanity [27]. Developing countries are the most affected by massive urbanization. Today, 1 billion people live in the slums, the most deprived are deprived of drinking water and sanitation, the cities then turning into “real health bombs” [28].

Cities are always born and develop near water, which is necessary for the biological and economic life of any community. However, for many years the countries of the North as well as those of the South have been confronted with an increasing speed of urbanization and a growing population, which leads to an increasingly important need for space [29]. In the cities of the South, the services in charge of water management are indeed faced with the challenge of accelerated urbanization of poverty: despite the fact that socio-economic inequalities and social polarization have increased, the heterogeneity of poor households has increased, including the increase in socio-economic inequalities and social polarization [30]. In Port-au-Prince, the water supply rate is less than 50% of the population [31]. The most

disadvantaged categories of the population in the RMPP do not have access to water under satisfactory or sufficient conditions [32]. These findings allow us to suggest that water is no longer the driving force behind the creation of human settlements; it seems to become one of the factors of health risks and of crisis or of urban violence.

In Haiti, DINEPA, a public institution responsible for executing state policy in the drinking water and sanitation sector, is struggling to fulfill its role [33]. In fact, Haitian cities, more particularly Port-au-Prince, where the demand for water is already high, are increasingly exposed to demographic growth which considerably affects water and sanitation infrastructures [15]. The conditions of water supply and sanitation, which were already precarious, deteriorated with the earthquake of January 12, 2010 [34].

The assessments of the burden of disease associated with poor WASH (Water, Sanitation and Hygiene) are 90% dominated by mortality from diarrheal disease and acute morbidity [35]. By combining the multiple health effects, some researchers and research organizations in the health sciences estimate that unsafe WASH is responsible for nearly a tenth of the global burden of disease [36]. Indeed, beyond diseases of the fecal-oral cycle, the scientific literature reports several pathologies resulting from the chronic effect of exposure to poor-quality WASH [37], particularly diseases chronic associated with chemical contamination of water [38].

According to IHE and ICF [39], “73% of the Haitian population uses an improved source of water. Access to an improved source is much more common in urban areas than in rural areas (95% versus 60%). 33% of the population has improved unshared toilets, mainly cesspools with slabs (21%) and a sanitation system connected to a septic tank (9%). It is in urban areas that the proportion of the population with access to improved unshared toilets is highest (43% compared to 23% in rural areas)”.

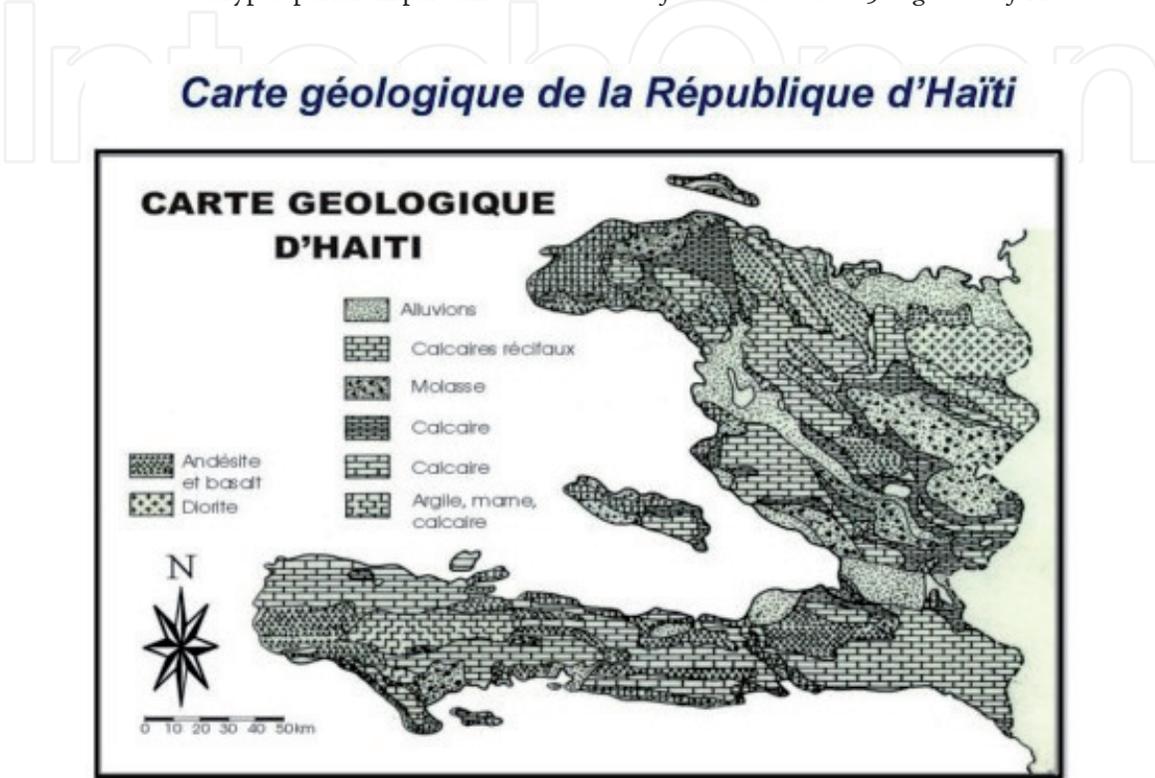
In Port-au-Prince, the risk of fecal contamination of the environment is particularly high. Clusters of fecal coliforms have been found in the water sources used to supply the population of the RMPP [40]. A more probable number (MPN) of 700 fecal coliforms per 100 ml was detected in the groundwater of the Cul-de-Sac plain [41]. This aquifer is the largest source of groundwater used by the population of the Port-au-Prince region to meet their water needs. These results highlight the existence of a bacteriological danger linked to these water resources for the health of consumers.

In addition, oocysts of *Cryptosporidium parvum*, a parasitic protozoan responsible for an infection called cryptosporidiosis, have been detected in surface water, in groundwater and in public water fountains [42]. During the cholera epidemic, declared in October 2010, *Cryptosporidium* oocysts ranging from 6 to 233 per 100 L of water were detected in water supply points in the RMPP [43]. Cryptosporidiosis is responsible in Haiti for 17% of acute diarrhea observed in children under 2 years of age and 30% of chronic diarrhea in patients infected with HIV [44]. *Cryptosporidium* oocysts are among the pathogens most resistant to conventional types of treatment such as chemical disinfection, for example [45]. The comparison of statistical data on *Cryptosporidium parvum* contamination of water resources in the City of Port-au-Prince, with those of two other cities (Cap-Haitien [43] and Cayes [46]) is presented in **Table 1**. These studies confirm the need for monitoring of the microbiological quality of water, with a view to reducing the morbidity of infections linked to the consumption of contaminated water.

In Haiti, the basement is primarily limestone [47]. **Figure 3** presents the general geology map of the country [48]. The northern watershed of the Massif de la Selle, the highest chain in the Republic of Haiti with an altitude of more than 2000 meters, is abundantly watered by rainwater [47, 49, 50].

City	Mean	Minimum	Maximum	Standard deviation	n	References
Cap-Haïtien	5053	3583	6088	1095	4	[43]
Cayes	28	3	63	25	5	[46]
Port-au-Prince	64	6	233	68	12	[43]

**Table 1.**  
 Statistical data on *Cryptosporidium parvum* contamination of water resources in 3 large cities of Haiti.



**Figure 3.**  
 Geological map of the Republic of Haiti [48] - (map: Reprinting with permission of authors).

This basin is of interest for the water resources of Port-au-Prince, it contains intensely fractured limestone, allowing the storage and circulation of underground water. It follows that this is a major aquifer, a real potential water tower for the RMPP [41]. The geological section of the northern watershed of the Massif de la Selle is shown in **Figure 4** [47]. The predominance of limestone in the geology of this aquifer increases the hardness of these water resources. The work carried out on the surface and underground water resources exploited, to supply the population of the Metropolitan Region of Port-au-Prince (RMPP), revealed a total hardness above 200 mg/L with concentrations in  $Mg^{2+}$  less than 7 mg/L [41, 51].

Studies on the health effects of hardness have shown that a total hardness concentration greater than 200 mg/L with a magnesium concentration less than 7 mg/L could affect various organs, including cardiovascular physiology [52]. At very high concentrations, calcium can negatively impact the absorption of other essential minerals for the body, in particular magnesium which is the agent of protection against the calcification of soft tissues due to myocytes [53]. The beneficial effects of water hardness in karst regions come from magnesium. Its deficiency could accelerate the development of atherosclerosis and the induction of platelet aggregation, thus promoting myocardial infarction and cerebrovascular pathologies [54]. The low  $Mg^{2+}$  concentration measured in the water resources of the RMPP may generate health risks for consumers exposed to the influence of

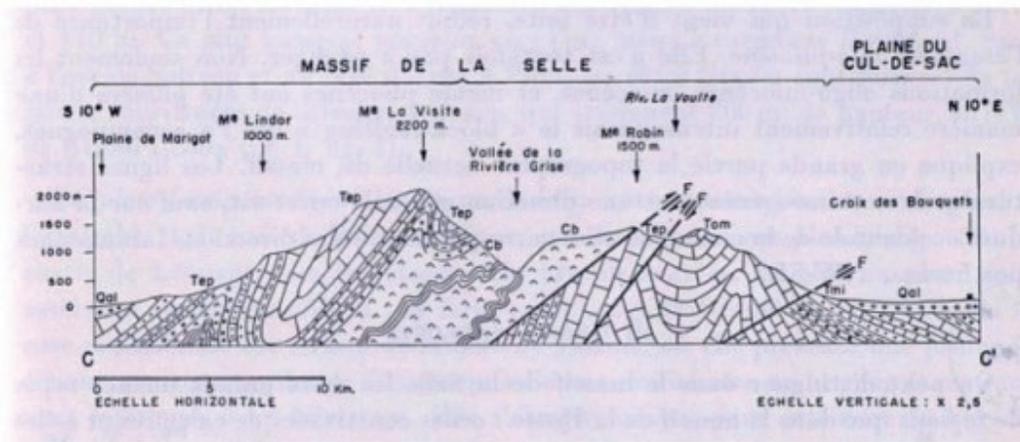


Figure 4. Geological section of the massif de la Selle [47].

geological and environmental factors. In Haiti, cardiovascular diseases have been placed for several years among the ten (10) leading causes of morbidity in the country [55]. In 2016, 29% of registered deaths were due to cardiovascular diseases [56]; this percentage was 57% for 2018 [57].

Fluorine concentrations ranging from 0 to 1.92 mg/L were measured in the resources of the RMPP. This concentration is distributed up to 1 mg/L in carbonate aquifers and from 1.00 to 1.92 mg/L in sedimentary formations [58]. This variation in fluorine can cause health problems, such as tooth decay in people (especially children) living in areas dominated by carbonate aquifers and fluorosis in people living in areas dominated by sedimentary formations [58].

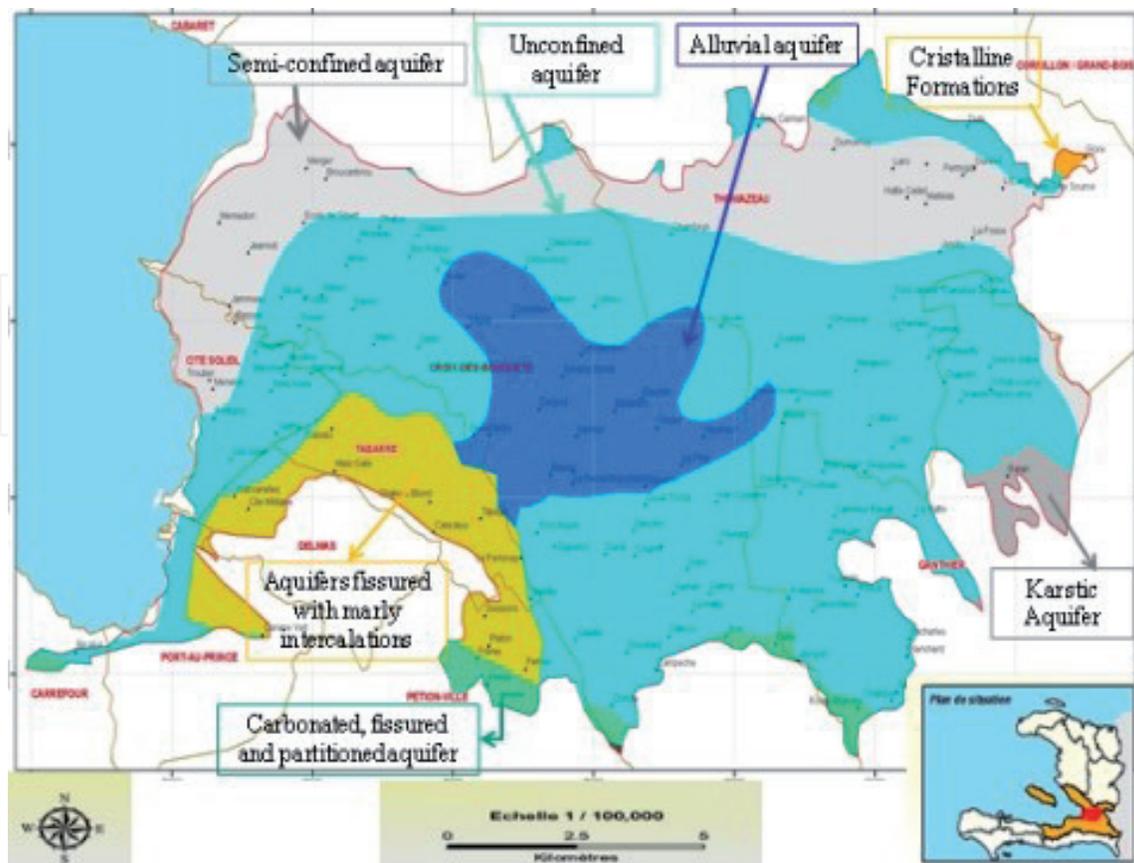


Figure 5. Map of the Cul-de-sac plain [62] - (map: Reprinting with permission of authors).

The salt contamination of the coastal aquifer of the Plaine du Cul-de-Sac (**Figure 5**) was investigated. According to Gonfiantini and Simonot [59], the salinity of these groundwater is the result of seawater intrusion following intensive exploitation. Between 1988 and 1999, the salinity of these waters increased by 246% [60]. Saline contamination of groundwater is manifested by a high concentration of chlorides, which is associated with dissolved solids and conductivity values in groundwater [61]. At chloride levels greater than or equal to 700 mg/L, salinity can cause problems with pregnancy toxemia or preeclampsia in pregnant women and high blood pressure [2].

Studies have shown the impact of urban pollutants on the physico-chemical quality of groundwater in the Plaine du Cul-de-sac [62]. Lead (40 to 90  $\mu\text{g} / \text{L}$ ), nickel (15 to 250  $\mu\text{g} / \text{L}$ ) and Cr (18 to 470  $\mu\text{g}/\text{L}$ ) concentrations were measured in boreholes in the Plaine du Cul-de-Sac [41, 63]. These values are well above the thresholds recommended by the World Health Organization (WHO) for water intended for human consumption [2]. The behavior of heavy metals (Pb, Cu and Cd) during their transfer into the slick was studied. The conclusions made it possible to understand that cadmium poses many more problems than lead and copper, by comparing their affinity to soil ( $\text{Pb}^{2+} > \text{Cu}^{2+} > \text{Cd}^{2+}$ ) [64].

### 3. Canaan: a shanty town built in a drought-stricken area

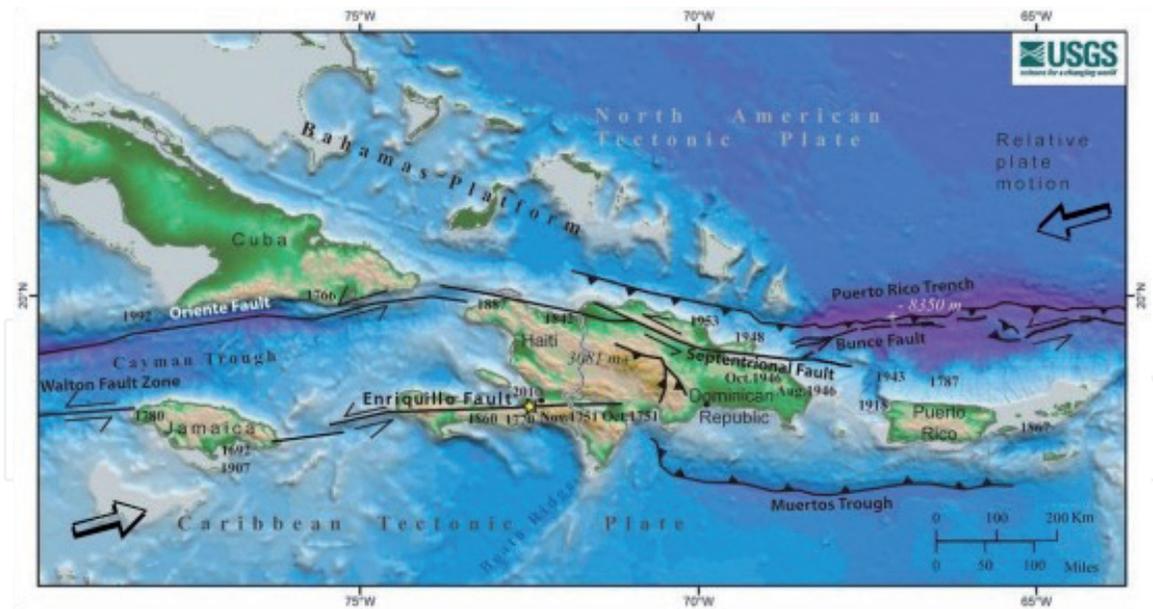
#### 3.1 Canaan: a new human settlement in the environmental and urban context of Haiti

The Republic of Haiti occupies the western part of the island of Hispaniola, the eastern part of which constitutes the Dominican Republic (**Figure 6**). It is located at the border of two tectonic plates, the North American plate and the Caribbean plate (**Figure 7**). The country is also on the path of tropical cyclones that originate in the Atlantic Ocean. Like the other territories of the Caribbean, the country is exposed to natural hazards and its history bears witness to these events. Between 1986 and 2016, Haiti recorded several major environmental events (floods, droughts, cyclones and the magnitude 7.2 earthquake on the Richter scale of January 2010).

The environmental and human damage generated by its natural disasters, more particularly that of the earthquake of January 12, 2010, has been the subject of several studies reported in the literature. Indeed, “in the history of urban disasters, the earthquake of January 12, 2010 occupies a special place. Not only in view of the



**Figure 6.** Topographic map of the island of Hispaniola (Haiti and Dominican Republic). <https://simple.wikipedia.org/wiki/Hispaniola>.



**Figure 7.** Map of the north American - Caribbean tectonic plate boundary. <https://www.usgs.gov/media/images/map-north-american-caribbean-tectonic-plate-boundary>.

extent of the losses and damage caused, but also of the lessons that can be drawn from them in terms of spatial diagnosis and land use planning. Understanding what happened to guard against a bereavement as immense as that caused by the 300,000 deaths in 2010 is a civic duty and an obligation of the state” [65]. Ribordy et al. [66] argue, “the risks engendered by nature and by human activity have accompanied humanity since its origins. In addition to the direct impact of these events on the life of the population, it seems appropriate to retain the intangible impacts (which, in the current state of knowledge, are not translated into monetary terms) such as the degradation of natural environments. and the loss of irreplaceable goods such as heritage”, but also the displacement and relocation of inhabitants as well as the increase in the process of urban sprawl [15]. Caught in the paradox of urbanization, the earthquake of January 12, 2010 raises many questions in the scientific community. Why are urban environments the most exposed today to the consequences of natural disasters? How can we understand that contemporary urbanization is intensifying despite the multiplication of disasters and the limits of management efforts [67]? How and why does the disaster produce new urban areas at risk or new vulnerable urban areas likely to contribute to new crises [68]? [...].

Answering these questions requires returning to the very concepts of urbanization, of the rural exodus which is one of the factors of slum development, as well as the function of land use planning in the structuring of human population in Haitian cities. Among the multiple causes of the rural exodus, the migrant’s search for a better standard of living should be put in the forefront [69]. The absence of an urban planning and viable housing policy, as well as the non-implementation of land use plans, when they exist, gives free rein to the anarchic development of cities. In fact, in the growth of Haitian cities, precarious slum-type housing has always prevailed. For 11,700 hectares urbanized at the end of the 20th century, Port-au-Prince had 1,802 shanty-town hectares [70]. In Port-au-Prince, “uncontrolled urban sprawl is, along with population growth, a powerful factor of vulnerability to so-called natural hazards. He played a major role in the process of producing vulnerabilities that contributed to the transformation of the hazards of the 2000s in Haiti into real crises linked to major disasters. These catastrophes were crises within the crisis” [68].

According to Gubry [69], “urbanization is in a way a culmination of ongoing economic processes, both those which are part of a development logic, and those which result from the destructuring of rural societies. In addition, urbanization often causes an exacerbation of conflicts between the population and its environment. The importance of the subject will be noted, insofar as the strongest urban growth is to be expected in the countries which are probably the most deprived of the means to cope with it. The urban environment often deteriorates in developing countries as a result of the low standard of living of the population, itself linked to unemployment. Municipal resources are very insufficient to maintain the quality of life: lack of sewerage system, inadequate water supply and garbage collection system, resulting in groundwater pollution; proliferation of pests (rodents, insects, bacteria, etc.)” [69].

In the cities of the South, demographic growth causes heterogeneity of poor households to various forms of lumpenproletariat in addition to socioeconomic inequalities and increased social polarization [30]. Beyond these anthropogenic phenomena and their socioeconomic consequences, it seems appropriate, in the specific case of Haitian cities, to take into account the marked mode of disaster management, according to Desse et al. [68] by “the absence of good coordination between numerous actors within the framework of what we will call humanitarian supervision. Popular strategies of rehousing or access to housing then developed after the catastrophes, hence the pressure on the peri-urban belts. Indeed, all the imbalances suffered by Haitian cities come from their risky growth. The poor occupation of space and the environmental degradation it induces are at the basis of the production of vulnerabilities that have contributed to disasters”.

It is in this environmental context characterized, among other things, by an absence of an urban development policy exposed by the earthquake of January 12, 2010 that the human settlement Canaan was founded. The first CANAAN occupants occupied the premises during the first months following the earthquake, ie February/March 2010 [70]. As of April 2010, Canaan lacked basic urban infrastructure such as water, sanitation, and electricity [15]. The situation of Canaan is, however, particularly critical because of the characteristics of the site and the circumstances which led to its rapid settlement.

### **3.2 Canaan: its creation and its history**

The 2010 earthquake was the founding element of many camps established in the metropolitan region of Port-au-Prince while waiting for the issue of the homeless due to the destruction of numerous housing losses to be addressed, and for the right to living in a viable space is applied. The omnipresence of camps throughout the devastated region highlights an often hidden population in Haiti with a major component, that of the poorest. Inside the camps - places of waiting - there is a diversity of people among whom their houses had been destroyed, others coming from disadvantaged neighborhoods and who found in the camps of better living conditions [71].

Canaan is located in the far north of the Metropolitan Region of Port-au-Prince (RMPP), about 18 km from the city center, precisely on a house formerly called Corail Cesselesse, in the communal section of Varreux II, Municipality of the Croix-des-Bouquets. Before 2010, this vast virgin and arid space housed a few peasant families who practiced animal husbandry. For more than 250,000 people, this space has accommodated informally, outside of any urban planning. This dry and hot region with low rainfall (on average 900 mm/year) was declared a public utility area in 1971 with a view to tourist development [72]. Among others, private projects of great importance were considered as part of a master plan for the development

of the North Pole. Canaan was the subject of another declaration of public utility published in the Official Journal *le Moniteur* of March 22, 2010 for the purpose of relocating the victims of the earthquake. This decision first appears to provide a solution to emergency needs following the numerous housing losses and under the weight of land pressure facing the metropolitan region of Port-au-Prince (RMPP). However, previous initiatives never went beyond the project framework for several reasons, including lack of political will for follow-up, lack of funding and the complexity of the land issue. Since then, this space has experienced rapid development with newcomers coming from all over, in search of better living conditions and land ownership [73] to constitute a vast informal habitat [71]. As a system of predatory land developed, “land speculators” saw the opportunity for cheap land to be valued [72]. However, the presidential decree declaring the zone of public utility in its article 2 - *Monitor* of March 22, 2010 - stipulates that “all construction work, road boring, subdivision or other exploitation of the land, as well as any transaction or real estate alienation” were prohibited there. But over time, the complexity of making it a public space given the high rate of compensation that this population would claim for their relocations would be far too costly. The geographic coordinates of Canaan are 18 ° 38 '46 "N, 72 ° 16 ' 23" W [74].

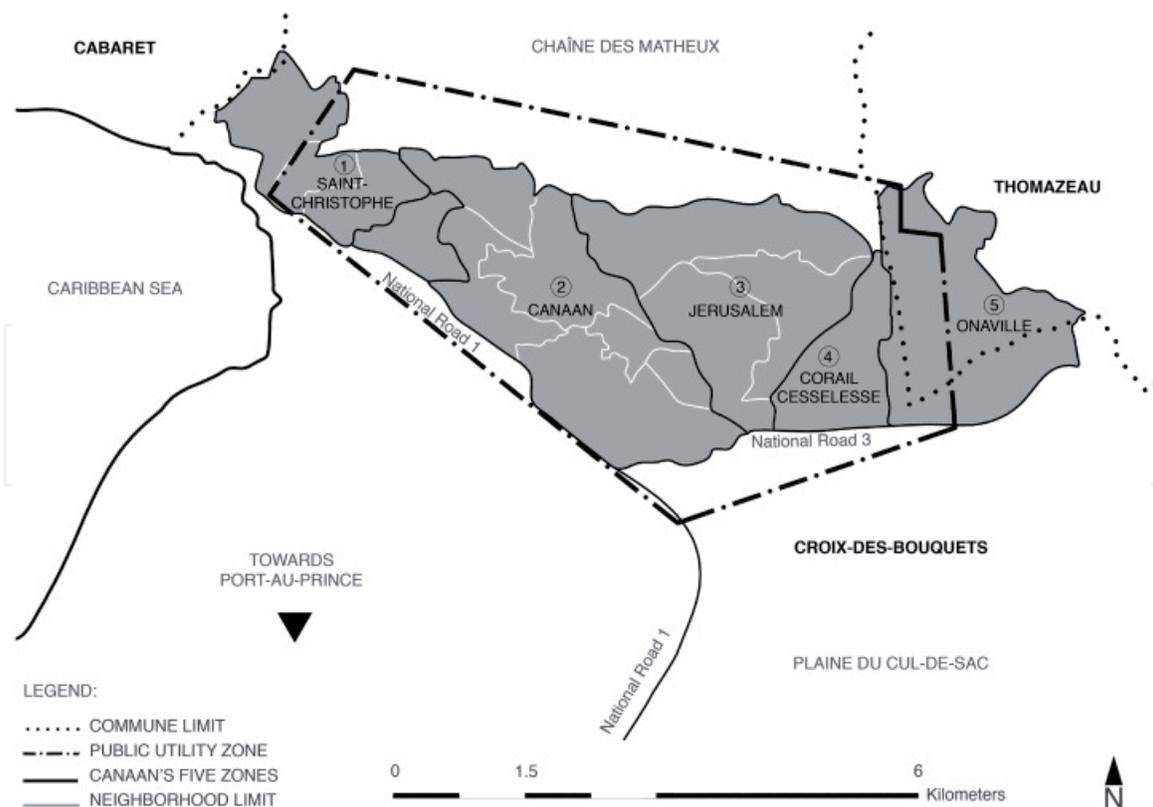
### **3.3 The territory of Canaan: morphology and modes of occupation**

Bodson et al. [75] consider that “the recent settlement of the territory of Canaan in the communes of Croix des Bouquets, Thomazeau and Cabaret is part of a major trend which affects all areas near Port-au -Prince. On the other hand, it constitutes a unique phenomenon by the speed of its emergence and by its importance. At the beginning of 2010, the territory was almost unoccupied. The trigger for this meteoric expansion was the presidential decree of March 22, 2010. It followed a very rapid “spontaneous” occupation of the territory”. **Figure 8** presents the map of Canaan [76].

The very dry climate and the very dispersed plant cover make the territory a semi-desert area. Along with the poor vegetation cover, the territory is exposed to three major natural environmental risks. Risks related to irregular surface water flows and the lack of availability of quality water have been identified, seismic risks and risks of landslide and surge of friable tailings [77].

In addition to the natural vulnerabilities of the territory, there were major deficiencies in the process of allocating plots and in the organization of services, which could not keep up with the accelerated pace of residential construction. When the post-earthquake emergency response organizations left, national and municipal public authorities did not take over. Besides, could they have done it in the face of the speed and enormity of the current phenomenon? In the absence of the involvement of national and municipal public authorities, the new inhabitants, in collaboration with numerous private initiatives, have organized themselves according to priority emergencies and limitations in the means available. Together with the increase in housing, a relatively dense network of streets and dirt roads (see map below) has thus developed under the control of “local solidarity” and has emerged with the help of private organizations (Protestant missions, Catholic organizations ...) a set of initiatives offering fragments of basic services. The result is a relatively large and complex urban fabric but private, despite the many partial achievements in progress, important basic services to the population, in particular as regards the availability of water for the daily needs of the population. and treatment of sewage and waste.

This situation is not unique to Canaan. It is found in various forms throughout the neighborhoods of the wider area of Port-au-Prince. It is nevertheless



**Figure 8.**  
*Map of Canean [76]- (map: Reprinting with permission of authors).*

particularly acute there because of the characteristics of the site and the circumstances which led to its rapid settlement. Canean is a very vulnerable epidemiological environment today. Little is known about living conditions there. It is in this perspective that we conducted a survey of a sample of 439 households [15]. Carried out within the framework of the research program “Water in the human settlements of the future”, of the Center for Research and Support for Urban Policies (CRAPU) of the University of Quisqueya, this survey aimed to analyze the problems of availability and use of water for households located in Canean and their possible link to the vulnerability of its population to water-borne diseases. Households were selected on the basis of a Simple Systematic Sampling (SSS) design. This plan had to adjust the sounding pitch to take into account the peculiarities of the terrain and as such must be considered non-standard. The selected households are spread over 6 territorial sections of Canean (11.62% in Canean 1, 18.68% in Canean 2, 38.50% in Canean 3, 5.01% in Canean 4, 8.66% in Canean 5, 17.54% in Jerusalem and Bellevue). These 6 sections do not cover the whole of the territory commonly referred to by Canean, but include most of the nucleus behind the current expansion [15, 75].

### 3.3.1 Socio-economic characteristics of households

The households appearing in the sample present characteristics similar to those highlighted by the ECVMAS 2012 survey [78] for the metropolitan area, but some traits are modified due to the contribution massive migration that Canean has experienced since the 2010 earthquake.

Heads of household are on average 42 years old. They are mostly men (60%). These figures contrast with the data from ECVMAS 2012 for the metropolitan area where the average age of heads of household is 46 and where the proportion of women heads of household is 49% [78]. Their level of education is generally slightly

lower than that observed in the metropolitan area. The vast majority of heads of household (98%) live in the household. 72% of these are married or “placed”.

4.56% of the households surveyed nevertheless have a dwelling provided by humanitarian aid. The homes are located in plots that are generally larger than those in precarious neighborhoods in the metropolitan area. The plots are not systematically contiguous. The result is a relatively dispersed residential space in contrast to the majority of urbanized spaces in the metropolitan area. Residential housing is systematically built on one level. The materials used reflect a very great precariousness.

These households have an average of 5.11 people. In the metropolitan area, this average is 4.5. There are many under 18 s in the households surveyed: 2.25 on average per household, which at least partially explains the difference observed compared to the metropolitan area. The household profile thus partially resembles the mononuclear family without however excluding the extended family profile. The size of the households leads to an overloading of inhabited spaces.

In addition to the overload of occupancy, there are major deficiencies in the services directly associated with homes. Toilets are systematically rudimentary or non-existent. Private toilets are nevertheless predominant (73%). These are very generally located near the inhabited structure or are contiguous to it. Access to electricity from city power is limited to 26.7% of the households surveyed.

Solid waste is treated in a very rudimentary manner. Evacuation by truck from the town hall is almost non-existent (0.5%). The majority of solid waste is incinerated, most often near the house, but dumping in the ravine or in vacant lots is also a common practice (16.6%). In addition, 5.3% of households do not specify what to do with their solid waste. In turn, wastewater receives virtually no specific treatment. For 87.2% of the households interviewed, wastewater is simply thrown outside. 3.2% nonetheless have a canal or ditch to facilitate the evacuation of wastewater, while the remaining 9.1% use another system without specifying the details.

### *3.3.2 Problems of water availability and use*

How are the problems of availability and use of water addressed in this environment marked at the same time by semi-desert climatic conditions, by very rapid population growth, widespread poverty, rudimentary development of residential habitats and degradation? of the environment associated with it? In Canaan, easily accessible quality water resources are systematically lacking. The rains there are relatively infrequent and flow quickly to the surface in a torrential manner. The water in the first levels of the aquifer is salty.

237 water points had been identified, the vast majority of which are located in the 6 sectors of the area covered by the survey. For 166 selected households, an average of 16% of the household head's income is devoted to water. For 25% of households, the percentage of water weight in monthly income exceeds 24% [15].

### *3.3.3 Vulnerability to diseases associated with the environment*

The vast majority of households settled in Canaan are confronted with extremely precarious situations which come from constraints from the natural environment, income limitations, installation conditions (land tenure, quality housing, lack of infrastructure) and the progressive degradation of the environment. The health conditions associated with this context have serious shortcomings and expose the population to increased risk of disease. The households contacted by the survey were affected in various ways by several diseases (diarrhea - 54%;

cholera - 3.6%; malaria - 28.9%; typhoid - 19.8%) associated with the modalities according to which health relations are managed at the environment.

The occurrences per household of the diseases mentioned were grouped together and calibrated into an “index of vulnerability to environmental diseases scaled from 0 to 10. The value 0 corresponds to the absence of any “environmental” disease in the household considered, taking into account the sector where it is located. The value 10 corresponds to a situation where all the households surveyed in a sector would have incurred all the diseases considered by the survey. Over the entire area covered by the survey, the vulnerability index to “environmental” diseases stands at 3.06. The vulnerability index is higher (3.10) in sectors 1, 2, 3 compared to sectors 4, 5 (2.97). On the other hand, this difference fades as certain social-demographic characteristics of households are taken into consideration, the quality of drinking water and water for other domestic uses, and the attitude towards - with regard to the various uses of water (whether or not to distinguish drinking water from other uses), supply systems, certain housing infrastructures, additional water treatment.

The vulnerability index to “environmental” diseases is positively correlated with the size of households (.16 \*\*), with the proportion of young people under 18 in the household (.16 \*\*), but more weakly with proportion of women in the household (.08). It is also negatively correlated in a very statistically very significant way with the quality of drinking water (-.25 \*\*) and with the quality of water for other domestic uses (-.22 \*\*). The explicit distinction by households between drinking water and water for other domestic uses seems to play an important role (F: 9.96, Sig. 002) on the level of vulnerability to environmental diseases. This index stands at 2.97 if the distinction is explicit, but rises to 3.32 otherwise. The choices of supply systems also seem to have a determining influence on the level of vulnerability to environmental diseases. If the drinking water supply is by gallon / sachet, the environmental disease vulnerability index is 2.98, but rises to 3.29 when using other water supply systems. The F-test (8.54) for the relationship between the two variables is statistically very significant (.004). The use of the truck-based supply system when it comes to water for other domestic uses also seems to have a beneficial, but statistically less precise, effect on vulnerability to environmental diseases (F: 3.61 Sig: .058). The environmental disease vulnerability index is 2.99 if the truck-based supply system is used, but rises to 3.17 if other supply systems are preferred.

Whether it is water for drinking or water for other household uses, a number of households resort to water treatment. Do these practices, which are both diverse and variable in their application, help reduce the vulnerability of households to “environmental” diseases? It should be noted first of all that these practices concern a limited percentage of households: 39.2% of households if it is water for drinking and 64.7% of households if it is water for other uses. Domestic workers.

With regard to drinking water, recourse to the Aquatab methods - sodium hypochlorite tablet - (2.95), water filter (2.91) and “Other” (2.59) seem to promote a reduction in vulnerability to environmental diseases. It is quite different if it comes to the use of sodium hypochlorite in liquid form. In this case, the Vulnerability Index increases (3.36) suggesting that this method, as used, makes the situation worse.

If it concerns water treatments for other domestic uses, the results of the statistical analysis are in the same direction as for the treatment of drinking water with regard to the System filter and Aquatab methods but are not statistically significant (F: 1.52, Sig: .20) for all the categories considered. In addition, the results are dominated by the more frequent use of sodium hypochlorite in liquid form, which appears to correspond to an increased vulnerability to “environmental” diseases.

Toilets and their use for the disposal of human excreta can be contaminating factors favoring the spread of environmental diseases. According to the survey data, the average differences in the index of vulnerability to environmental diseases after the methods of disposal of human excreta are not statistically significant. However, we should highlight the almost generalized use of private latrines (73% of households surveyed) and the higher average level of the index of vulnerability to environmental diseases associated with it (3.11), a situation which suggests poor conditions on the health plan in the organization and use of private toilets.

The various factors mentioned interact together on the level of vulnerability to environmental diseases. Their joint incidence was studied by multiple regression.

All the independent variables retained in the model give rise to statistically significant estimates that follow the same logic as that suggested by the bivariate analysis. The estimates highlight the vulnerability to environmental diseases of two categories of people: those under 18 and women. The quality of the water, whether it is drinking water or water for other household uses, contributes to reducing vulnerability to environmental diseases. Implicitly, this type of relationship concerns two major modes of water supply: the purchase of drinking water by gallon / sachet and the delivery of water by truck. These two supply methods are indeed decisive for the quality of the water. According to the estimates obtained, they also contribute directly to the reduction of vulnerability to environmental diseases.

#### **4. Conclusion**

Improving living conditions in a sustainable perspective in Canaan presents major challenges. What avenues of intervention should be encouraged or prioritized to facilitate favorable development for the population while taking into account the heavy constraints that weigh on their daily lives? Examination of the data collected by the survey opens up some avenues for reflection that could guide interventions in the field, including from a short-term perspective.

The methods of integrating households in Canaan compromise the quality of life in many aspects: WASH of questionable quality, poor housing, lack or deficiencies in infrastructure and / or basic services, lack of treatment of solid and liquid waste, serious deficiencies in health infrastructures and their functioning, profound degradation of the environment.

In practice, however, local community groups occupy an almost exclusive key position in responding to the basic service needs of the populations. A greater margin for improving the situation is nevertheless accessible from the involvement of these groups and the mobilization of the local population. However, it is a complex challenge to take up because it requires from the population, at the same time an awareness of the situation and of the current issues, sustained and systematic steps of consultation and decision-making. Organization, mastery of a varied range of skills and discipline to promote the best accessible development conditions while minimizing negative external repercussions on the community and the environment.

In the current context of scarce resources and the destitution of almost all households, many loopholes are likely to arise and remain in this community approach. Analysis of the survey data revealed several:

- The non-distinction on the part of many households between drinking water and water for other domestic uses,
- the ineffectiveness of home water treatments,

- the operation of private toilets,
- methods of disposal of wastewater, solid waste and human excreta.

To address these difficulties, targeted interventions to be implemented in consultation and with the participation of local communities would benefit from being considered.

This is particularly the case for water used by households. Measures taken by households to treat water seem unlikely at this stage to even reduce vulnerability to environmental diseases. Household training programs would no doubt be appropriate. But the problem could also be corrected at its source by means of systematic and controlled treatment of the water delivered by gallons and / or by truck.

Complementary to this systematic and controlled treatment, the density of water access points could be intensified. Well coordinated by community groups, this operation could also help reduce spatial disparities in water prices for households. This type of improvement would particularly help to reduce the percentage of households not distinguishing between drinking water and water for other domestic uses.

A support program for the functional establishment of private washrooms would also help reduce the risk of contamination and reduce vulnerability to environmental diseases.

It is also important that local health care organizations take into account the most vulnerable categories of the population, including young people and women.

In setting up these adjustments, consultation with local groups, their initiative and their involvement are essential conditions for success.

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