

Nature and Nurture: Determinants of Water-Related Diseases in Children from Dakar

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Abstract

In Senegal, despite recent health progress, water-related infections still constitute an acute urban health concern, particularly with regard to children. In the capital, Dakar, the rapid urbanization of recent decades lead to high population densities with diverse socio-economic profiles, in a very heterogeneous urban space. Often, underprivileged families also reside in areas with deficient living arrangements and subpar infrastructure, which means that Dakar's children may be exposed to very different risks for water-related infections.

With this in mind, the present thesis analyzes the determinants of water-related diseases, focusing on the effects of behavior and the immediate environment. A mixed-methods approach is used, combining statistical models with semi-structured interviews. In terms of data collection and analysis, the general approach of the study follows a deductive and quantitatively-driven design, whereby the construction of the qualitative instrument is built upon the initial quantitative results.

In the context of an ongoing debate regarding whether it is private actions or external physical conditions which determine the transmission of water-related diseases, the present study's results point to both spheres. Findings also indicate that health-related behavior in the family is often a function of the immediate environment, calling attention to the need to take into account characteristics of the wider area, when investigating infectious diseases. The research also points out that, in developing contexts, some of the commonly used statistical indicators may not convey an accurate picture of living conditions. Thus, complementary qualitative analyses may be necessary for a proper understanding of the risk factors involved in the transmission of water-related infections.

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List of Acronyms

ACTU-PALU “Paludisme et diversité de l’environnement urbain africain : un enjeu majeur pour la mise en place des thérapies à base d’artémisinine”.

D_{eff} design effect.

DALY disability-adjusted life year.

DHS Demographic and Health Surveys.

EA enumeration area.

EIR entomological inoculation rate.

GIS Geographic information system.

ICC intraclass correlation.

ITN insecticide-treated net.

LCA Latent Class Analysis.

LLITN long-lasting insecticide-treated net.

MCA Multiple Correspondence Analysis.

MDG Millenium Development Goal.

MICS Multiple Indicator Cluster Surveys.

MIS Malaria Indicator Survey.

PCA Principal Component Analysis.

UNICEF United Nations Children's Fund.

VPC variance partition coefficient.

WHO World Health Organization.

Part I

INTRODUCTION

Chapter 1

Infectious Diseases in Sub-Saharan Africa

1.1 General context

A marked discrepancy characterizes causes for disability-adjusted life years (DALYs) in children between high-income and low-income countries. Leaving neonatal disorders aside, while in richer areas, the main burden of disease is due to congenital diseases, in poorer areas infectious diseases (particularly diarrheal diseases, malaria and lower respiratory infections or pneumonia) still occupy the highest places in terms of causes for child mortality and morbidity (Institute for Health Metrics and Evaluation (IHME) 2017). They are also among the most frequent childhood illnesses and causes of attendance at health services in developing countries, as well among the main killer diseases among young children (Troeger et al. 2017; WHO 2018a).

In 2010, an estimated 7.6 million children died in the first 5 years of their life and among these, 64% (4.9 million) died of infectious diseases (Liu et al. 2012). This burden of disease varies greatly around the world in general and among developing countries in particular, with Africa bearing almost half (3.6 million) of all estimated deaths. Also here, the proportion of deaths due to infectious diseases is the highest, at almost three quarters (73.2%) (Liu et al. 2012).

This is particularly the case in Sub-Saharan Africa, where despite numerous national and international efforts, the major burden of infectious diseases still constitutes one of the biggest public health issues and insufficient progress contributed to the failure to attain Millenium Development Goal (MDG) #4 on reducing child mortality (Liu et al. 2012).

Infectious diseases are caused by pathogenic microorganisms and can be transmitted from one person to another, directly or indirectly. Among these, water-related diseases are characterized by the fact that water is involved in their transmission, by means of four possible routes (Cairncross and Feachem 1993; Eisenberg et al. 2001):

- water-borne (by and large the cause of diarrheal diseases, due to either drinking contaminated water or to eating food that has been prepared with contaminated water)
- water-washed (diseases affecting the skin and the eyes, caused by poor personal hygiene)
- water-based (transmitted by aquatic organisms, such as worms, which penetrate the skin while bathing)
- water-related insect vectors (spread by insects – in most cases mosquitoes – which breed in or near stagnant water)

The current research looks at the two most frequent pathways for transmission of water-related diseases: the water-borne diarrheal one and the vector-borne one (Institute for Health Metrics and Evaluation (IHME) 2017). It focuses on the determinants of these types of infections in children, specifically those living in the urban context of Dakar, the capital city of Senegal.

Compared to adults, children suffer a heavier burden of disease due to water-borne and mosquito-borne diseases, a vulnerability due in part to an immature immune system at younger ages, and in part to the increased exposure that children inherently face. Moreover, in developing contexts, other additional factors, such as malnutrition, contribute to a weakened immune system and thus render children more vulnerable to these types of infections (Shope 2014; UNICEF and WHO 2009).

Concerning the first route – that of water-borne infections – water-borne infections diarrheal diseases still represent one of the most common causes of health-care seeking and hospital admissions for children, especially in developing countries (Fischer Walker et al. 2013). Diarrhea remains the second cause of death in young children worldwide and a quarter of all child deaths – thus more than AIDS, malaria and measles combined – are attributed to diarrheal infections (UNICEF and WHO 2009). The African region is particularly affected and, while progress has been made, Sub-Saharan Africa still lags behind other regions in terms of diarrheal disease DALYs (Troeger et al. 2017).

With regard to the latter route – that of vector-borne water-related diseases – of particular concern is malaria, which has seen a rise in the number of cases since 2016, indicating the stall of progress and a possible resurgence of malaria (Maxmen 2017; WHO 2018b). Far from the previously set goals of eradicating the disease, efforts undertaken in the last century to fight it turned out more or less as a succession of disappointments. Furthermore, chloroquine resistance, followed by sulfadoxine pyrimethamine resistance and then by mefloquine resistance quickly spread around the Globe, calling for a new drug to fight malaria (Hanboonkunupakarn and White 2016). The advent of artemisinin-combination therapies provided a period of reprieve in the struggle to contain the disease. These therapies use artemisinin and another companion substance (also known as a partner drug) to fight the malarial parasite.

However, in the last decade, an increasing number of reports have raised concerns concerning artemisinin-resistant strains of the parasite in several South-East Asian countries (Ashley et al. 2014; Spring et al. 2015). The development of resistance to artemisinin and its partner drugs could mean that this “new” therapy of choice may become ineffective, leaving the disease without a cure (WHO 2018b).

Another area of concern regarding resistance is that of mosquitoes, which risks compromising the recent advancements in malaria control. According to the World Health Organization (WHO) (WHO 2019a), already 68 countries have reported insecticide resistance, which, if proven consistent over time, constitutes a rapid development and spread of resistance to insecticides in mosquito popula-

tions.

On the vaccine front, although four new molecules are being currently tested (Phyo et al. 2016; Wells et al. 2015), these are still in development, with an estimated one third probability of success. In the meantime, there is currently no malaria vaccine which successfully completed the testing phase (Wells et al. 2015).

Another mosquito-borne infection (but with no specific antiviral drugs), is dengue fever. Estimations regarding the disease, both in terms of geographical area affected and in terms of intensity, are characterized by a high degree of uncertainty and range from one third to over half of the world's population (Brady et al. 2012). While a vaccine has been made available since 2016, its price remains largely prohibitive for most of the population at risk and its efficacy in preventing dengue infection is successful in only around half of cases (Villar et al. 2015).

In most developing contexts, water-related diseases tend to differ not only in urban areas compared to rural ones, but also between cities and even across different areas of the same city. This is because in cities of the developing world, the immediate environment tends to be very diverse, due to the rapid and often unplanned urban growth (Mendez et al. 2000; V. Robert et al. 2003; United Nations Human Settlements Programme 2003). Consequently, the urban space creates a varied environment: within the same city, access to education and health care or sanitation are often very heterogeneous. This impacts the infectious disease landscape both in terms of etiology and in terms of routes of transmission. Hence, the substantial variations in transmission between different areas of the same city, often reflect, at least in part, these disparities in environmental conditions. This can then affect the health of individuals differently, putting certain categories more at risk than others. For example, a study done in Ouagadougou, Burkina Faso, showed great prevalence disparities of parasitemia among school children, between 24.1% in the center and 68.7% at the periphery (Wang et al., 2005 cited by Alirol et al. 2011).

Thus, although both deficient living arrangements and subpar infrastructure are to be found in urban as well as in rural areas, their concentration in poorer and overpopulated neighborhoods in cities

generates significantly increased public health risks (Matte and Jacobs 2000).

1.2 The Case of Senegal

Like many other African countries, Senegal has been recently experiencing a double burden of disease, as high rates of infections persist in the context of an increase in chronic non-communicable conditions (Niang-Diene and Salem 2015). Vector-borne and diarrheal diseases still constitute the main burden in terms of child morbidity and mortality: in 2017 malaria and diarrheal diseases were estimated to be responsible for over 30% of all deaths among children between one and five and for a fifth (20%) of all deaths among children between five and ten¹(Institute for Health Metrics and Evaluation (IHME) 2017).

In terms of etiology, most diarrheal episodes, especially in younger children, are attributed to rotavirus infections (Troeger et al. 2017), whereas malarial infections constitute the main vector-borne disease. The map of the *Plasmodium* parasite prevalence follows a general North-South pattern, with the highest rate of confirmed cases in the hot and humid South and relatively fewer cases in the dry North (WHO 2014). All cases are due to the *Pl. falciparum* species, carried by several species of the *Anopheles* mosquito.

The capital, Dakar, represents the country’s main area of economic development and a “primary city” in the region, attracting businesses and workers from throughout West Africa (United Nations Economic Commission for Africa 2017). This contributes to a relatively high population growth rate, making Dakar the most populous city in the country, with nearly a quarter of its total population (Agence Nationale de Statistique et de la Démographie 2014; Agence Nationale de Statistique et de la Démographie 2015). The fast urban growth and high population density mean that in Dakar, the environment is fundamentally different from the rest of the country and heterogenous within the city, across neighborhoods.

¹Lower respiratory infections (pneumonia) are estimated as responsible for 14% and 8% of deaths, respectively (Institute for Health Metrics and Evaluation (IHME) 2017).

Thus, environmental factors which can affect the health of children, do not influence all categories of population to the same extent and in the same way.

Moreover, a general increase in precipitation during the annual rainy period has been reported in the Sahel, since the 1990s and generally, it is the regions with lower annual rainfall which exhibited the highest increase (L. Diop et al. 2016). This, in the context of infrastructures which are often lacking or not adapted to large quantities of precipitation, can lead to flooding during the rainy period. Since floods pose a threat both in terms of contaminated water and in terms of favoring mosquito breeding, this recent increasing trend in annual rainfall in the area could have an impact on water-related diseases in the capital of Senegal.

Chapter 2

General Aims and Structure of the Study

Given the persistent burden of infectious diseases transmitted by means of water in most of the developing world and particularly in Sub-Saharan Africa, as well as the lingering inequalities in terms of vulnerability and capacity for treatment, this thesis intends to look at the determinants of such infections. Its focal point will be the effect that behavior and the immediate environment have on febrile and diarrheal water-related diseases in children living in a dynamic urban space, the city of Dakar (WHO 2013a). Although the etiology is different between these two types of diseases, literature shows that they share numerous common risk factors, which may be mediated by protection measures, environmental sanitation infrastructure and socio-economic conditions (Fobil et al. 2012).

Thus, as general objective, the present thesis focuses on the network of determinants for urban febrile and diarrheal diseases in children, identifying the role and contribution of the factors pertaining to behaviors and to the immediate environment (household and neighborhood). Along this line, the thesis also explores ways to synthesize and group these factors, in order to create a comprehensive causal image, all the while using parsimonious statistical models.

The reason for focusing on an urban space is that, although better equipped in terms of medical infrastructure and inhabited by

better-educated and wealthier populations, the urban advantage in terms of health is greatly reduced or sometimes even reversed when controlling for socio-economic factors (Bocquier, Madise, et al. 2011). Therefore, urban spaces constitute not only the cradle of most public health innovations, but also the source of many serious public health threats (Galea et al. 2005).

Moreover, in much of the developing world, urban growth has been very rapid in recent decades, with pockets of poverty and crowding, which pose additional risks in terms of infections (Osborn 1998; Ramin 2009). In this context – and going even further in the direction of spatial heterogeneity – there are increasing challenges to the idea of treating slums as a “homogeneous mass of urban poor” (Harpham 2009, p. 109).

Consequently, this thesis seeks to investigate the effect that living in a certain area has, on the risk of a water-related infection. While studies have repeatedly found the existence of such effects, “we do not know enough about the causal mechanisms which produce them, their relative importance compared to individual characteristics such as education, and under which circumstances and where these effects are important” (van Ham et al. 2012, p. 3).

The thesis also looks at the possible interactions between the two spheres of interest – behavioral and the environmental – as well as with socio-economic determinants. The hypothesis underlying this approach is that the impact of environmental factors on febrile and diarrheal diseases in children varies, depending on the socio-economic status of the child’s family, which can mediate the impact of the milieu for the better or for the worse. Since “the interaction of many negative factors multiplies the risks” (Omenn 1998, p. 222), focusing only on the role of individual, family-related or environmental, while disregarding the other levels, would not provide an accurate assessment of the risk factors involved in water-related disease transmission.

The thesis also aims to identify risk factors which favor co-morbidity of fevers and diarrheas, as well as the determinants that differ from one pathology to the other. Co-morbidity refers to the additional conditions which concur with a primary disease or disorder, within a relatively short time-frame (Valderas et al. 2009). In other words, it

has to do with the appearance of two or more diseases or disorders. The reason this poses specific problems in terms of public health is that interacting disorders can have synergistic effects (Black et al. 2003). Consequently, the child's health outcomes are more likely to be poor than in the case of mono-morbid episodes, their management tends to be more challenging and the costs involved are higher (Valderas et al. 2009). While the co-occurrence of several diseases can be simply due to coincidence, most often the conditions appear together or at a short interval because they have the same environmental and/or behavioral determinants (Black et al. 2003).

In order to address these aspects, the study will use a mixed methods approach, combining quantitative and qualitative data and analyses. In practice, the starting point constitutes a larger scale survey, from which certain units are subsequently selected on the basis of characteristics of interest for this study. These units are then studied more in-depth, using qualitative methods. (Bryman 2004a). In doing so, I aim to adopt a pragmatist approach, of scientific experimentation over philosophical concepts, by prioritizing findings over prior knowledge or pre-established rules (Maxcy, 2003, cited by Small 2011).

The thesis is structured into five parts, of which the first – containing this chapter – constitutes the introduction and rationale of the study. The second part is a conceptualization of the theoretical account and analytical scheme: Chapter 3 sets the context of urban health in Senegal and the specificities of its capital, Dakar. Chapter 4 discusses the characteristics, pathways of transmission and challenges regarding water-related diseases, as well as their possible determinants according to existing literature. Based on this information, Chapter 5 sets the objectives, research questions and hypotheses from which the study sets off, and places it in the context of existing research.

The third part deals with the data and methods used. Since the research employs a mixed methods approach, this part is split in two chapters. Chapter 6 first presents the project “Paludisme et diversité de l’environnement urbain africain : un enjeu majeur pour la mise en place des thérapies à base d’artémisinine” (ACTU-PALU), the data of which I am using for the statistical modelling in this

study; subsequently, it explains the steps undertaken and the indicators used to achieve the quantitative side of the results. Chapter 7 details the qualitative side of the data and methods, namely the interviews conducted, the ACTU-PALU community survey and the techniques employed to analyze them.

The fourth part contains the results and is split into five chapters, following the objectives pursued in each of them. Thus, after the descriptive results presented in Chapter 8, Chapter 9 analyzes the general risk factors for water-related illness episodes in children, as well as the interdependencies between them. Subsequently, Chapter 10 investigates more in depth the role of the environment, the relative part of each “layer” of the surrounding and how the various spheres of the milieu can impact disease transmission. Chapter 11 examines the possible interactions and specific relationships between socio-economic factors, the child’s age and environmental conditions, in terms of favoring infection. Finally, Chapter 12 screens determinants by type of symptom and identifies those factors which favor the co-occurrence of more than one type of water-related disease.

The last part concludes this thesis: Chapter 13 places the results obtained in the context of other existing studies dealing with water-related diseases in children, then discusses the strong-points and challenges concerning this study, as well as some measures undertaken to limit potential bias. Chapter 14 concludes the thesis: it first presents the possible implications of the findings in this study, both in terms of individual measures to prevent water-related diseases and in terms of public policies aimed at reducing the burden of this type of infections; finally, it lays forth possible paths for future research on the topic of water-related in urban children from developing contexts.

Part II

CONCEPTUAL FRAMEWORK

Chapter 3

Urban Health and Infectious Diseases

The present study is circumscribed to the urban space, more precisely to the city of Dakar, the capital of Senegal. The reason for this focus on a large urban area is that in cities in particular, rapid and sometimes spontaneous urbanization often leads to spatial promiscuity as well as to pockets of poverty and poor health infrastructure, thus favoring the spread of microbes. Under these conditions, certain categories of urban children find themselves at greater risk than their rural counterparts (Mbugua et al. 2014; Osborn 1998).

Accordingly, this chapter deals with two main aspects. Firstly, I will be briefly going over the main questions to which literature on urban health aims to reply, as well as over the three types of analyses which have been so far most widely used to investigate, in a comparative manner, the relationship between city characteristics and the health of city-dwellers. After reviewing how the relationship between cities and health has been addressed in scientific literature, I will subsequently focus on the particularities of Dakar as the capital and largest urban area of Senegal and on the specific health challenges it faces in terms of water-related diseases.

3.1 Cities and Health

Thus, looking at the impact of cities on their residents' health, two main questions arise:

- What are the characteristics of a city?
- In what way(s) do these characteristics and city life in general affect its residents' health?

The first question, of what makes a city, has been a longstanding subject of scientific and administrative debate, a discussion which largely exceeds the scope of the present study. Consequently, the pages to follow will only briefly address some of the main features of the urban space, so as to better circumscribe the context of the research. Conversely, sociological theories and debates, on themes such as the link between urbanization and population growth or the forces which drive urbanization, will not be discussed here.

As a result of the aforementioned debates, several indicators and frameworks of analysis have been elaborated for describing cities, and each of them has received criticism from one or another part of the scientific community (Vlahov and Galea 2002). Conservative approaches most often define a city by contrasting it to a village, thus opposing "urban" to "rural" (Galea et al. 2005). However, more recent approaches introduced the idea of a rural-urban continuum and a focus on the dynamic of cities (urbanization) and on their state (urbanicity).

Urbanization, although difficult to define, is usually employed to refer to the process by which population proportionally shifts from rural to urban areas. In other words, it refers to the process by which a country experiences an increase in the share of its urban population, to the detriment of its rural one. Thus, it denotes a course of continuous changes in terms of size, density and structure of cities (Cyril et al. 2013). Complementary to urbanization, urbanicity refers to the unique characteristics and living conditions (both physical and social) of urban areas, at a given moment (Vlahov and Galea 2002). Although in current practice urbanicity is often approximated by population density (Cyril et al. 2013), a large amount of components assemble to form urbanicity, aside from population density. Among them, the economic activity, sec-

tor and earnings of the population, types of markets in the area, local infrastructures (transportation, sanitation, communications and medical), as well as the types of housing and the social structure of the inhabitants (Dahly and Adair 2007; Jones-Smith and Popkin 2010).

Consequently, while urbanization is dynamic and refers to the processes that affect the structure of cities), urbanicity is an image at a given moment, referring to urban living at a given point in time (Ompad et al. 2007). Another aspect to be noted is that urbanicity does not refer to a rural-urban dichotomy, but to a continuum on which human settlements are placed (Cyril et al. 2013; Dahly and Adair 2007). This is particularly noteworthy in the products of rapid urbanization from much of the developing world, where peri-urban and squatter settlements coexist with more planned urban areas, creating very diverse urban contexts (Dahly and Adair 2007).

In general, the urban context is composed of the social environment, the physical environment and the urban resource infrastructure. Each of these three components is influenced by conditions at the municipal, national, and global levels and each of them has a potential impact on human health (Ompad et al. 2007). When looking at the mechanisms and direction in which the social and physical environment and the urban infrastructures impact on urban residents' health, three types of comparisons are generally undertaken and each of them will be briefly discussed in the following pages:

1. the urban population and context versus the rural ones
2. population and conditions across several urban areas
3. intraurban disparities

In the pages that follow, I will provide a brief explanation, characteristics and examples for each of these three approaches.

1. Urban-rural comparisons

The first type of urban health studies contrasts the urban environment to its rural counterpart. Until a few decades ago, this was the most common approach to urban health and also the general

perspective of governments in the monitoring process of the human development performance of their countries (United Nations Human Settlements Programme 2006). This approach aims to decant the effect that the specificities of urban environment have on different aspects of health and well-being. Existing literature has shown that the type of place of residence plays a crucial role on health in general and on child health in particular, determining to a large extent aspects like infant mortality, obesity or breastfeeding practices (Jones-Smith and Popkin 2010).

This impact can be at the same time beneficial and deleterious to health, since urbanization brings with it both advantages and disadvantages, which impact on residents' health. On the one hand, urban areas usually have higher income, more intense internal and external trade, economic and social growth. On the other hand, this brings along increased rates of pollution, crowding and insufficient planning of infrastructure (sometimes leading to the creation of slums), increased inequalities and higher crime rates (Cyril et al. 2013).

In Sub-Saharan Africa, most studies dealing with rural-urban health differences have generally concluded that living in cities constitutes an advantage (Bocquier, Madise, et al. 2011). One of the reasons cited for this is that, in the developing world in general and in Sub-Saharan Africa in particular, urban populations tend to have better access to sanitary infrastructures than their rural counterpart (Dos Santos, Ouédraogo, et al. 2015). This discrepancy dates back to the establishment of colonies in Sub-Saharan Africa, where cities were built so as to ensure adequate provision of water, sanitation and healthcare for the colonial settlers (Gould, 1998, cited by Bocquier, Madise, et al. 2011).

However, in terms of health outcomes for children, the urban advantage is greatly reduced or sometimes even reversed when demographic and socio-economic factors are taken into account (Bocquier, Madise, et al. 2011). One possible reason for this may be that, especially in recent decades, Sub-Saharan cities have suffered the strain of an extremely rapid urban growth and slum growth, at 4.58% and 4.53%, respectively, the highest in the world (United Nations Human Settlements Programme 2006). This is coupled with a lagging growth in per capita gross domestic product (GDP) of

the developing Sub-Saharan African countries, which translates to a lower general access to improved health and sanitary infrastructures (The World Bank 2018). These two trends have had a significant impact on infectious diseases in particular, since pathogens often enhance their virulence in rapid host-to-host passage. This means that crowding boosts infections and that, for now, urbanization favors microbes in developing contexts (Osborn 1998).

2. Inter-urban comparisons

The second type of urban health studies typically compares health outcomes between several cities or towns, across different countries or within the same one (Ompad et al. 2007). Some studies limit themselves to identifying discrepancies in the patterns of disease from one city to another and formulating possible reasons for these discrepancies. Such is the case of Zhao and colleagues (2012), who found some significant differences in the prevalence of diarrheal disease across eight cities in China and hypothesized that a possible explanation could be related to dietary habits. Similarly, comparing dengue incidence in two cities from Brazil – Niterói and Rio de Janeiro – Roriz-Cruz and colleagues (2010) concluded that there is a possible link between unplanned urbanization – together with poor primary-care system – and dengue occurrence.

Other studies may go one step further and introduce city-level variables to test for potential effect on health outcomes, often looking at the effects of pollution (Amegah and Agyei-Mensah 2017; Katoto et al. 2019; Rajé et al. 2018). However, when using the city as the unit of analysis, studies do not account for intra-city variation and thus implicitly assume that the exposure is the same (or at least similar) for all residents (Ompad et al. 2007). This is obviously not the case in most of the developing world, where considerable variation and inequalities exist within one urban area. The rapid urbanization which took place in these areas often lead to the development of peri-urban settlements; in some of these settlements poverty, crowding, lack of environmental planning and poor access to services pose additional health risks (Dahly and Adair 2007)

3. Intra-urban comparisons

The latter approach uses finer spatial units and looks at the inequalities within one urban area. Although this type of research often tends to be hampered by limited data on the relation between intraurban variations and their effects on health, recent insights into the growing disparities within many cities constitute “fertile ground for investigation” (Vlahov and Galea 2002, p. 58). This type of approach, of a narrower spatial division, may prove itself useful especially when looking at developing countries, which often experience very large inequalities (Harpham 2009). Here, urban growth has yielded important intra-urban amenity disparities, especially between formal and informal areas or slums (Dagdeviren & Robertson cited by Dos Santos, Ouédraogo, et al. 2015).

These intra-urban disparities carry potentially significant implications on health. For example, there is now reliable evidence that, in general, the overall socioeconomic status (SES) of a neighborhood impacts on its residents’ health, beyond the effect of individual SES (Flournoy and Yen, cited by Harpham 2009). This could be linked to several factors, such as the residents’ health-related conduct or the housing quality. In this context, it seems meaningful for the present study to look at urban water-related diseases by using a finer spatial division and taking into account determinants at levels smaller than the city itself, especially in the context of a varied urban space, as is the case of Senegal’s capital, Dakar.

3.2 The Case of Senegal

Senegal is a Sub-Saharan African country, situated on the West coast of the mainland (See Figure 3.1). It is one of the least developed countries in the world ranking 164 of 189 on the 2017 Human Development Index, with a score of 0.505 (United Nations Development Programme 2018). Senegal is also one of the poorest countries, with an estimated GDP per capita of 1367\$ in 2017, placing it 209 out of 246 countries and territories included in the World Bank database (The World Bank 2018).

In terms of climate, Senegal is characterized – for most of its surface – by a tropical climate with two seasons: the dry season and the wet season. The most notable exception to this are its northern

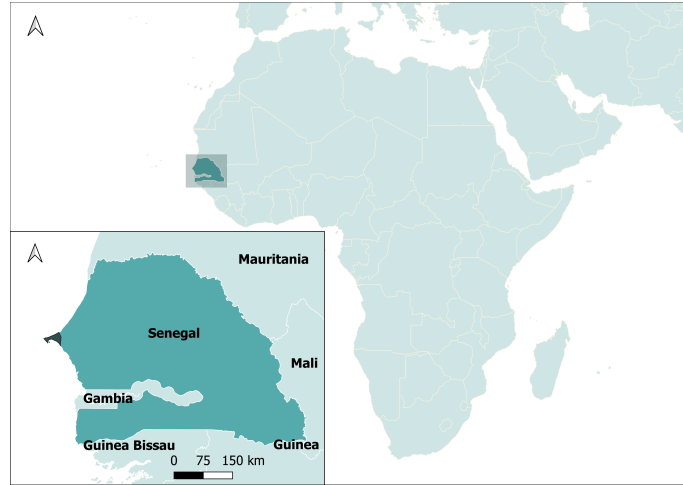


Figure 3.1: Map of Senegal

Map created with QGIS (QGIS Development Team 2019) using OpenStreetMap Foundation 2018 data

regions, which lie in a sub-tropical and semi-arid belt, known as the Sahel (McSweeney et al. 2012). In recent decades, the mean annual temperature has increased and this trend is projected to continue in the decades to come (McSweeney et al. 2012). With regard to rainfall, especially in the Sahelian region, there is high variability from one year to another and the last two decades have seen rather unusually high rainfall quantities (McSweeney et al. 2012). For the period between 1984 and 2013, a positive trend in precipitations has been recorded throughout Senegal's meteorological stations (L. Diop et al. 2016). Moreover, projections estimate that the proportion of total annual rainfall that falls in heavy events will increase in the coming decades (McSweeney et al. 2012). This, in turn, is likely to create new challenges in the management of water-related diseases.

In the past four decades, the population of Senegal has experienced a dramatic 2.6-fold population increase, from just under 5 million in the 1976 census, to over 13.5 million in the 2013 one (Agence Nationale de Statistique et de la Démographie 2014). In 2014, the country's population was estimated at 13.9 millions, with an annual increase rate of 2.7% that is expected to continue in the coming years (Programme National de Lutte contre le Paludisme

2016). In terms of urbanization, Senegal (as Sub-Saharan Africa in general) tends to be less urban than the North and the South of the continent (Dubresson 2003). However, compared to the Sub-Saharan part of the continent, Senegal maintains a higher than average proportion of urban population (See Figure 3.2). The 2013 census found slightly less than half (45%) of Senegal’s population to be living in cities (Agence Nationale de Statistique et de la Démographie 2014), while The World Bank’s estimate for 2017 was 47% (The World Bank 2019).

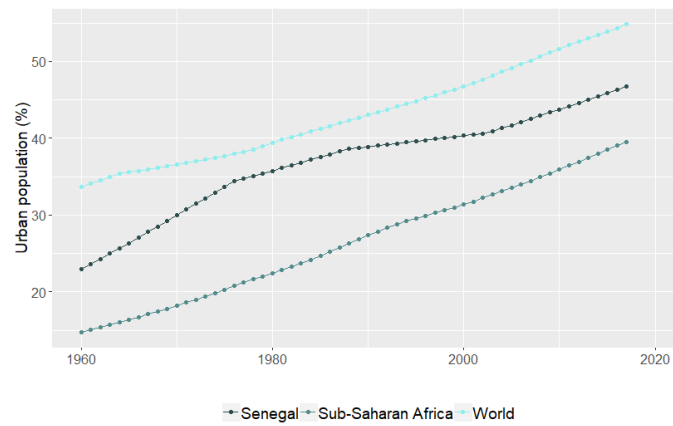


Figure 3.2: Comparison of the Urban Population Percentage

Source of data: The World Bank 2019

Of this urban population, the vast majority lives in large cities, of over one million inhabitants (Dubresson 2003). In fact, half of the country’s urban population lives in the capital region of Dakar, which – being over 96% urban – lies far ahead all other regions in the country (Agence Nationale de Statistique et de la Démographie 2014).

Urbanization in Senegal, just as in the rest of Sub-Saharan Africa, is happening at a swift rate and migration to cities is important (Sambé-Ba et al. 2013). For example, in much of Sub-Saharan Africa, a high migration towards cities is one of the reasons for the persistence of a relatively high urban fertility rates, as migrants generally tend to be young adults (McMichael, 2000, cited by Ompad et al. 2007). This swift rate of urbanization has prompted certain authors to liken the accelerated urban growth of the last decades as

an “urban crisis” (Stren and White, 1993, cited by Dubresson 2003). This refers mainly to the context in which urbanization in the region is taking place, which is of the lack of real industrialization, high unemployment rates, a largely informal economy, widespread poverty and a general disorganization of regulatory systems (Bocquier 2003; Dubresson 2003).

3.2.1 Urbanization and urbanicity in Dakar

In Dakar, the fast rate of urbanization is accentuated by the city being also an international port. This makes Dakar, in itself, an engine of urbanization (Bocquier 2003; Scott et al. 2013). Also, although Senegal is one of the poorest countries in the world the Dakar region tends to be relatively wealthy compared to the rest of the country (Organisation for Economic Co-operation and Development (OECD) 2002; The World Bank 2018; United Nations Economic Commission for Africa 2017). The capital constitutes by far the main area of economic development in the country and attracts businesses and workers from throughout the West African region. This contributes to a relatively high rate of population growth, which between 2002 and 2013 was on average of 3.4% (Agence Nationale de Statistique et de la Démographie 2015). In 2013, the population of Dakar was estimated at just over 3.1 million inhabitants, thus almost a quarter of the country’s entire population (Agence Nationale de Statistique et de la Démographie 2014; Agence Nationale de Statistique et de la Démographie 2015).

Administratively, the region is composed of four departments: the city of Dakar – the most populous – accounting for almost 40% of the region’s inhabitants, Pikine, with around 35%, Rufisque, with almost 13% and Guédiawaye, with around 12%. Population densities across these four departments are also highly heterogeneous, with Guediawaye being the most, and Rufisque the least, densely populated (See Figure 3.3).

As already mentioned, an important component of Dakar’s accelerated urban growth is related to inter-urban, as well as rural-urban in-migration (Bocquier 1994). This ever-increasing population of the city leads to high density habitats and to alternative strategies with regard to housing (Scott et al. 2013).

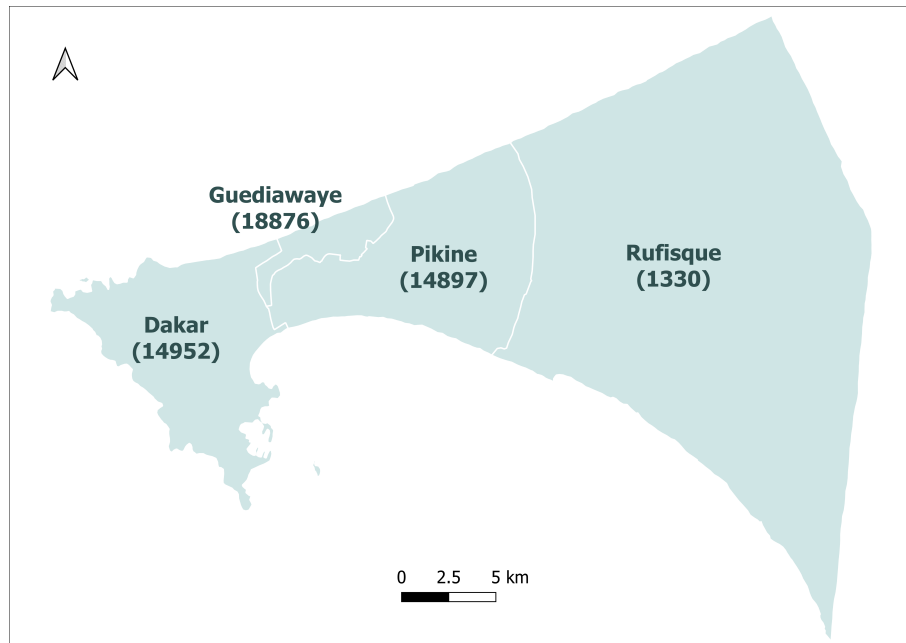


Figure 3.3: The Departments of Dakar with Population Densities (inhabitants/km²)

Map created with QGIS (QGIS Development Team 2019) using Agence Nationale de Statistique et de la Démographie 2015; OpenStreetMap Foundation 2018 data

As in many cities, housing in Dakar is organized around “neighborhoods”, which constitute a rather vague, but socially structuring geographical level, of variable size, not available in census data, but an important geographical landmark to individuals (Lalou 2008).

Geographically, Dakar is located in the Cap Vert peninsula, between 17°10' and 17°32' West and between 14°53' and 14°35' North, and covers an area of 550 km² (Service Régional de la Statistique et de la Démographie de Dakar 2009). Due to its location and to being almost surrounded by the ocean, the climate of the Senegalese capital is strongly influenced by trade winds. The relative humidity in the area is around 25%, while temperatures vary between 17°C and 25°C from December to April and between 27°C and 30°C from May to November. The wet season is relatively short, of around three to four months, between June and October (Service Régional de la Statistique et de la Démographie de Dakar 2009), with important variations from one month to another and with most of the rain-

fall occurring in August and September (C. Diop and Sagna 2011). However, recent climatic changes were observed in Dakar, affecting – among others – temperatures and rainfall. Between 1970 and 2009, there was a general tendency of increasing rainfall (C. Diop and Sagna 2011). Similarly, in the last decades, rainy seasons have experienced more and more abundant precipitations (L. Diop et al. 2016).

As a result, in the last two decades, the wet season was particularly rainy, with abnormally abundant precipitations (C. Diop and Sagna 2011; L. Diop et al. 2016; Lalou 2008). These abundant precipitations, combined with the fact that houses are built on lowlands in several neighborhoods, often leads to striking floods (Cissé and Sèye 2015; C. Diop and Sagna 2011). In turn, substantial floods may constitute an aggravating factor for water-related diseases, given the fact that, in Dakar, sanitation provision happens largely outside of city planning and urban management, by means of both formal and informal service providers (Scott et al. 2013).

Within the city, there is also a high degree of heterogeneity, with several microclimates adding to the longitudinal pluviometric variability. For example, significant differences in terms of pluviometric vulnerabilities were noted between Nord-Foire-Azur and Hann-Maristes, the latter experiencing the regular overflowing of its “lake” during periods of abundant rainfall, as well as the stagnating waters thus formed, which sometimes mix with wastewater (C. Diop and Sagna 2011).

Hence, different neighborhoods experience the recent climatic changes in various ways, depending on their geomorphological and urbanistic characteristics. In terms of terrain, Dakar is composed of three geomorphologic landforms: dunes, interdune depressions (niayes) and plateaus (C. Diop and Sagna 2011). The geomorphic and urbanistic differences (particularly heterogeneity in terms of paving and building height) from one area to another yield different wind conditions and favor floods in certain areas.

A particular case is that of slums, which are urban areas lacking basic services (such as sanitation or electricity), with substandard housing often in hazardous locations, characterized by overcrowding and social exclusion (United Nations Human Settlements Pro-

gramme 2016). Hence, underprivileged situations generally represent the norm in slums, which exist in Dakar just as in other Sub-Saharan African big cities. The reasons often cited for their existence are mainly the scarcity of jobs, shortfalls in the offer of adequate housing from authorities and the rapidly growing urban population (Bocquier, Beguy, et al. 2010). Slums are characterized by a general deficit in terms of access to water and sanitation, by general poor housing conditions and by crowding, while their inhabitants are, on average, relatively poor and with lower levels of education (Ramin 2009; United Nations Human Settlements Programme 2003).

In conclusion, slum dwellers often face a threefold disadvantage:

- improper infrastructure (United Nations Human Settlements Programme 2006; United Nations Human Settlements Programme 2016)
- being generally young and recent migrants, originally from rural areas and facing adaptation problems to new settings (Bocquier, Beguy, et al. 2010)
- being, on average, generally less educated and hence more prone to biomedically inefficient health behavior (United Nations Human Settlements Programme 2003)

These high inequalities between slum and non-slum dwellers of Sub-Saharan Africa often translate into health outcomes in children (Ramin 2009). In this context, for the same pluviometric episode in the city of Dakar, different neighborhoods and categories of population will experience different quantities of precipitation (due to the landform specificities of each area) and different flooding characteristics (due to the differing quality of public infrastructures across the city). This leads to unequal exposure of inhabitants to the risk of infectious diseases both water-borne and vector-borne ones, as certain bodies of stagnant water may form or overflow. These water bodies sometimes mix with wastewater, as the evacuation of liquid household waste proves challenging at times, during the rainy season (C. Diop and Sagna 2011).

3.2.2 Water-related diseases in Senegal and in Dakar

In Senegal in general, the occurrence of water-related diseases is both endemic and seasonal, being most frequent during the rainy season (Sambe-Ba et al. 2013). On the one hand, diarrheal pathogens multiply and mosquitoes grow faster, given the high temperatures in Senegal (Hashizume et al. 2007; Programme National de Lutte contre le Paludisme 2015). On the other hand, precipitation positively influences both the rate of inoculation of mosquitoes and the multiplication of enteric protozoa¹ (National Research Council 2001; Programme National de Lutte contre le Paludisme 2015).

With regard to mosquito-borne diseases, a significant amount of literature has concentrated on malaria, while dengue and chikungunya outbreaks and possible transmission have been less studied. Concerning malaria, Dakar is generally considered to have a low transmission rate and, for the last decade of the 20th century, Imbert and colleagues (1997) estimated that more than half of the *Pl. falciparum* parasitemic inhabitants of Dakar had been infected outside of the capital. A study done in Dakar from October 1999 to October 2003 and aiming to quantify *Borrelia* infections, found a *Plasmodium* prevalence of 7.8% in blood samples from 7750 patients with fever at the Institut Pasteur in Dakar (Brahim et al. 2005).

Dakar faces a seemingly paradoxical situation, whereby although the official general prevalence of malaria is not particularly high, the usage of antimalarial medication in children is significant (A. Diallo, Dos Santos, et al. 2012). However, the authors found that this low general prevalence of the disease hides important discrepancies between neighborhoods (A. Diallo, Ndam, et al. 2012). These persisting disparities within the boundaries of the capital were also recorded by official data (see Figure 3.4).

During a 2015 outbreak of malaria occurred in Senegal, with almost half a million confirmed malaria cases (Programme National de Lutte contre le Paludisme 2016). Of these, nearly 40 thousand cases

¹For more details regarding mechanisms, see Chapter 4

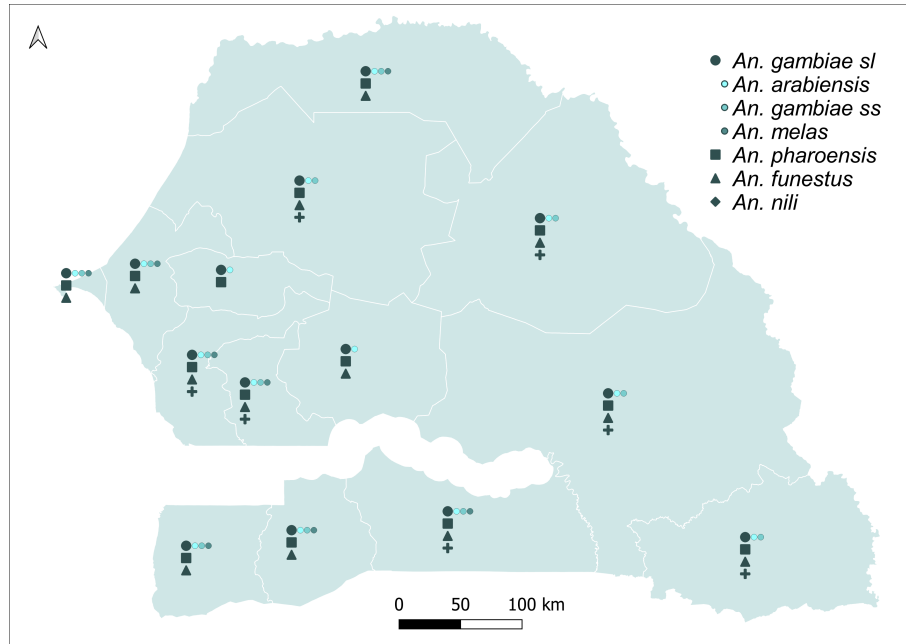


Figure 3.5: *Anopheles* Species in Senegal

Map created with QGIS (QGIS Development Team 2019) using OpenStreetMap Foundation 2018; Programme National de Lutte contre le Paludisme 2015 data

Several species of *Aedes* mosquitoes have also been captured in Dakar, namely *Ae. aegypti*, *Ae. metallicus* and *Ae. vitattus* (Machault et al. 2009; Pages et al. 2008). To my knowledge, there are no estimates regarding more recent rates of prevalence or incidence, but a 1986 dengue outbreak in Dakar saw the documentation of two strains of dengue virus in individuals who had not left Dakar in the previous 15 days, which may suggest the existence of local transmission (Saluzzo et al. 1986). Subsequently, in 2009, a dengue outbreak occurred in Senegal during and just after the wet season (September to December), with most cases occurred in Dakar (193 out of 196 confirmed cases). This, again, indicates probable transmission happening within the boundaries of the capital (Faye et al. 2014).

Outbreaks of chikungunya, on the other hand, have not been documented in Dakar, but in Senegal at large: recent outbreaks occurred in 2006 and 2015, each affecting several individuals, but none of them affected the region of Dakar (Pistone et al. 2009;

WHO 2015a).

Looking at diarrheal infections, a study conducted between March 2009 and December 2010 in the urban region of Dakar, found that rotavirus was the main cause in younger children during the dry season, while bacterial infections (especially due to *Salmonella*), were more prevalent during the rainy season (Sambe-Ba et al. 2013).

Despite the fact that rotavirus is the leading cause of acute gastroenteric episodes in children, few studies have documented rotavirus-induced diarrhea, in Senegal in general (Dia et al. 2015; UNICEF and WHO 2009). In a study done in three hospitals from Dakar between February 2011 and February 2012, the pathogen was isolated in 65 children from a sample of 103 aged 0 to 5 with diarrhea (Dia et al. 2015).

Regarding cholera, since the first 644 documented cases of cholera in 1971-1972, when the current pandemic hit the African continent, Senegal has regularly experienced cholera outbreaks, with the most notable recent one in 2005 (WHO 2010). The peak of the outbreak was at the end of March and beginning of April, with an average of 3500 new cases weekly. However, after a period of decline, the wet season brought with it a resurgence, mainly in the Dakar and – to a lesser extent – Diourbel departments. The aftermath of the two waves of the 2005 epidemic was 31719 cases with 458 deaths, thus a case-fatality rate of 1.44%. The outbreaks since have been, although frequent, less virulent.

In conclusion, it appears that city life raises specific challenges in terms of public health, most notably in areas of rapid or haphazard urban growth. In order to investigate these challenges, going past the classic rural-urban dichotomy and looking at the finer spatial scale can help identify discrepancies between different areas of the same city. In the case of Dakar, disparities with regard to mosquito-borne diseases have already been documented, as well as the local transmission of water-related diseases in general. However, relatively less information is available as to which categories are most vulnerable in the urban region of Dakar and what are the additional risk factors that these categories face.

Chapter 4

Determinants of Water-related Diseases: What We Know So Far

This chapter constitutes a critical synthesis of relevant literature, which addresses the particularities of the pathologies considered, as well as their risk factors. In an effort to mitigate language bias, namely the fact that studies which are more likely to be published and accessed are in English (Fewtrell and Colford 2004), this review includes articles in both French and Spanish, as complement to the majority of English-language studies. In terms of setting, I will, as much as possible, review studies focusing on Sub-Saharan areas. However, on aspects where literature from Sub-Saharan contexts is scant, I will also include studies focusing on other areas of the developing world.

Both vector-borne fevers and diarrheas are infectious water-related diseases, meaning they are caused by pathogens that can be transmitted from one person to another, directly or indirectly (WHO 2015b). However, although febrile and diarrheal diseases often have similar risk factors, the process of causation is different. In this context, the current chapter will be divided into two parts. The first part will deal with the particularities of each disease, the pathogen which is responsible for it and its transmission path. The second part will focus on the potential risk factors for these pathologies,

following a simple structure: firstly, I will present the basic mechanism by which the risk (or protective) factor in question potentially influences infection; secondly, I will present potential challenges or sources of bias in the research or measurement of the aforementioned factor; and thirdly, I will provide a brief review of research results regarding the determinant and its impact on each type of pathology.

4.1 Disease Characteristics

4.1.1 Diarrhea

Definition, Pathogens and Transmission

Diarrhea refers to passing loose or liquid stools 3 or more times a day (or more frequently than normal for the individual), lasting from a few days to several weeks and is a common symptom of several possible gastrointestinal infections (Boschi-Pinto et al. 2009; WHO 2017b). These include bacteria, viruses, protozoa and helminths (Rego et al. 2005). There are approximately two dozen diarrheal agents worldwide (Mosley 1984). Most often though, diarrhea is caused by either rotavirus, *Escherichia coli*, *Shigella* or cholera (Black et al., 1980, cited by Myaux et al. 1997; UNICEF and WHO 2009). These pathogens are extremely prevalent in poor populations from developing countries, which may sometimes lead to multiple simultaneous infections (Mosley 1984).

Of these, Rotavirus is the leading cause of acute diarrhea, accounting for about 40% of all hospital admissions due to diarrhea among children under five worldwide (Dia et al. 2015; UNICEF and WHO 2009). Although cholera is often the cause of diarrheal disease and hence often thought of as a major cause of child deaths due to diarrhea, most lethal cases occur among adults and older children (Black et al., 1980, cited by Myaux et al. 1997; UNICEF and WHO 2009).

The paths by which infection can occur are either transmission human-to-human by means of the environment (meaning, most often, the contamination of inanimate objects, of water or air); transmission human-to-human of pathogens which have multiplied in the environment; human-to-animal-to-human by means of the environ-

ment; and animal-to-human by means of the environment (Curtis et al., 2000, cited by Rego et al. 2005). This being said, infection occurs most often in a faecal-oral manner, either directly or indirectly, by the transmission of pathogenic agents which have multiplied in the environment (Curtis et al., 2000, cited by Rego et al. 2005).

Studies and Advancements

Today, diarrheal diseases presently affect around 1.7 billion children under five annually, with more widespread transmission throughout developing countries (WHO 2017b). In these contexts, diarrhea still accounts for a significant proportion of childhood deaths, after relatively little progress made in recent decades regarding case management (Sreeramareddy et al. 2017).

Research regarding diarrheal diseases faces two main challenges. On the one hand, there is the aspect of the multiple definitions in use for circumscribing diarrhea and the diarrhea-free period which separates two diarrheal episodes. On the other hand, particularly for studies which rely on self-reported data, there is the aspect of reliability and of the recall period.

With regard to the first aspect, that of definitions of diarrhea and of the diarrhea-free period, differences are usually not significant enough to cause problems: although there is great variability in terms of definitions, the most commonly used one is of three or more loose or watery stools in 24 hours, whereas episodes are usually separated by a period of at least two or three diarrhea-free days (Boschi-Pinto et al. 2009; Bukenya and Nwokolo 1990; Moy et al. 1991).

However, the aspect of the recall period for self-reported diarrheal episodes does sometimes pose comparison and potential bias problems. While a shorter recall period is clearly preferable, it increases significantly the cost of data collection, in order to gather a large enough number of cases for statistical analyses. However, past a certain limit of time, self-assessment in post factum is severely affected by memory bias (Woldemicael 2001). Opinions with regard to how long this maximum limit should be, in order for the data to still be reliable, are mixed. While certain authors consider that any recall period exceeding 48 hours poses methodological risks, it

is generally accepted that a period of maximum two weeks provides reasonably accurate data (Fewtrell and Colford 2004).

Another methodological problem related to self assessment of diarrhea is that, as opposed to medical check-ups, the former measures the subject's (or his/her tutor's) perception of health and the importance they place on illness symptoms, which vary according to socio-economic factors, education and attitudes towards hygiene (Seigel et al. 1996; Woldemicael 2001). This could mean that, for example, more educated individuals may be more prone to detect, remember and declare a past illness.

4.1.2 Vector-borne diseases

Vector-borne diseases are caused by a pathogen (be it a virus, a bacteria or a parasite), transmitted by a hematophagous arthropode. In African contexts, this is most often by a female mosquito, which infects humans or animals (Fontenille et al. 2010). While most vector-borne diseases are nowadays circumscribed to tropical areas, they have historically been present in colder areas as well, reaching as far North as Southern Europe and even the Scandinavian countries (Fontenille et al. 2010; Keiser et al. 2005). Worldwide, the mosquito-borne disease which creates the most important burden in terms of public health is malaria, but other diseases, like dengue or chikungunya are increasingly becoming areas of concern for morbidity and mortality in children living in tropical areas (Tolle 2009). A situation which affects more and more contexts is related to the increase in (the detection of) co-morbid febrile episodes in children. Thus, while malaria remains the main source of acute febrile illnesses, an increasing proportion of febrile children with malaria are also diagnosed with other sources of (non vector-borne) fever, such as upper respiratory tract infections and pneumonia (Matheson 2016).

Malaria

Definition, Pathogens and Transmission

Malaria is a protozoal infection, caused in humans by four species of the *Plasmodium* genus: *falciparum*, *vivax*, *ovale*, *malariae* (Tolle 2009). The vectors of transmission are the females of about 30-40

species of the *Anopheles* genus of mosquitoes, which typically bite at night-time (Centers for Disease Control and Prevention 2010; Pages et al. 2008). Anopheline mosquitoes exist in most areas of the world, including those where malaria has been eliminated, thus posing a constant threat of re-emergence in these areas. However, not all species are as efficient in transmitting *Plasmodium* parasites (Centers for Disease Control and Prevention 2010).

The first three stages of *Anopheles* – egg, larva and pupa – last between 5 and 14 days and are aquatic, since the eggs are laid directly on water, after the female obtains a full blood meal. It is only in the last, adult stage, that anophelines can transmit the *Plasmodium* parasite and this stage can last up to a month, but is generally of one to two weeks' duration (Centers for Disease Control and Prevention 2010).

Adult females fly in the dark and guide themselves, for finding a host, on traces of carbon dioxide, released by all animals, and on characteristic human odors. When landing, however, the heat radiating from the human body also plays a significant role (Spitzen et al. 2013).

The flight distance of anophelines is generally below 1.6 kilometers. In a study dating from the beginning of the 20th century (Le Prince and Griffiths 1917), approximately 900 to 1000 stained mosquitoes were released in nature and then a few of them were re-captured after a few days. The maximum flight radius thus obtained was 5565 feet (around 1.7 kilometers), past which no stained mosquito was found.

A study from 2004 by Kaufmann and Briegel, using 22-hour flight trials on *An. gambiae*, found that the maximal flight distances of females depended on their previous meal. Thus, blood-fed females could fly up to 9 kilometers, compared to 3 kilometers in the case of starved females. However, although *Anopheles* females may disperse along several kilometers, their proportion declines exponentially with distance (Thomas et al. 2013). Thus, while 50% of adult females moved within 386 m from the nearest breeding site, almost all of them (95%) remained within a radius of 1.671 kilometers (Thomas et al. 2013).

The disease, in its non-severe form, presents a wide range of clinical

manifestations, but without a pathognomonic symptom ¹. The non-specific symptoms most often cited are fever, headaches, and vomiting (F. Robert et al. 1996). Among these, the most commonly associated with malaria symptom is fever, experienced by 92% of patients (Genton and D’Acremont 2003, cited by Trampuz et al. 2003).

Studies and Advancements

Among mosquito-borne diseases, malaria affects by far the largest number of people, despite recent improvements which have limited the geographical spread of malaria (Sullivan 2010). The past century has seen an increase from 0.8 billion to 3.4 billion people at risk, due to the constant increase of population in the remaining affected areas and to the adaptation of the malarial vector – the *Anopheles* mosquito – to urban ecosystems, in the context of its rather recent resistance to insecticide (Matthys et al. 2006; V. Robert et al. 2003; Sullivan 2010). In recent years, around 300 million cases were reported annually, of which around 1 million lead to deaths (WHO, 2006, cited by Stratton et al. 2008). The vast majority – approximately 75% – of these deaths occur in Sub-Saharan countries, where malaria cases and deaths have arisen steadily since the late 1970s, accounting today for 90% of the total malarial burden (Yusuf et al. 2010). Young children constitute by far the most vulnerable category, with circa 700 000 deaths yearly below the age of five (Keiser et al. 2005).

For diagnosis, clinical malaria is often defined as “fever with parasitemia” (Sullivan 2010). However, relatively few studies use this definition, primarily due to practical considerations. Therefore, research typically relies to either one or the other.

In the case of using parasitemia as proxy, the risk is of over-diagnosing malaria, especially in contexts where the population is exposed to the parasite from a younger age (such as the case of Sub-Saharan Africa). Early exposure to the parasite leads to acquired immunity in the population (Clarke et al. 2002). Therefore, an individuals’ body may tolerate a certain parasite

¹Pathognomonic symptoms are those signs which characterize one disease and that disease only. Thus, the presence of pathognomonic symptoms indicates, without a doubt, that a particular disease is present

load without setting off the disease. Moreover, parasitemia often lacks appropriate diagnostic in surveys, since it requires blood samples. Hence, household surveys usually only record whether an individual has had a fever, rather than confirmed malaria (Filmer 2005; WHO 2013b). It is also the definition used to assess progress made against malaria, in the context of the MDG #6, as it is relatively straightforward to assess. Hence, the indicator for malaria treatment refers to the proportion of children under 5 with fever, who received artemisinin-based combination antimalarial drugs (UNICEF and WHO 2015). In the same approach, since 1995, in Senegal the National Plan of Fight against Malaria follows this same presumptive treatment (Baxerres and Le Hesran 2004). However, in certain cases, to mitigate for the possible over-diagnosing of malaria, the likelihood of a respondent having a positive test for malaria can be modeled from the parasite prevalence in the area and individual and household characteristics (WHO 2013b).

Since *Anopheles* mosquitoes tend to prefer clean and natural water bodies for reproduction, both prevalence and incidence of malaria are far more important in rural areas than in urban and peri-urban ones (Staedke et al. 2003). In a meta-analysis of malaria transmission in Sub-Saharan Africa, Robert and colleagues (2003) have calculated an average entomological inoculation rate (EIR) per residential area. EIRs are a common measure, which estimates the number of bites by infectious mosquitoes per person, during a certain period of time. Thus, the authors found an annual average EIR of 7.1 in the urban centers, 45.8 in peri-urban areas, and 167.7 in rural areas (V. Robert et al. 2003).

This being said, recent years have seen an increase in urban malarial episodes. Although malaria was traditionally considered to be rare in urban areas, due to the breeding preference of the *Anopheles*, studies have repeatedly reported their adaptation to urban environments. An entomological study in Dakar, carried out from May 2005 to October 2006, caught 4117 and 797 *An. gambiae* in the neighborhoods of Bel-Air and Ouakam respectively (Pages et al. 2008). The presence of the vector in urban areas means that transmission can no longer be considered as exclusively rural.

Although in past decades the only species of the *An. gambiae* to

be observed in the Dakar area was *An. arabiensis* (Awono-Ambéné and V. Robert 1999), this more recent study by Pagès and colleagues (2008) found three species of the complex: although *An. arabiensis* was the most prevalent ($> 98\%$), the study team also found *An. melas* ($< 1\%$) and *An. gambiae stricto sensu* ($< 1\%$). Infected mosquitoes were caught only during the winter period between September and November, in both Bel-Air and Ouakam (Pages et al. 2008).

Dengue

Definition, Pathogens and Transmission

Subject to a dramatic increase in geographic distribution in recent decades, dengue fever has become hyperendemic in all of the tropical world (Gubler 2004). It has become the most widespread of arboviruses, with 50 to 100 million infections every year (Bley 2010; Hales et al. 2002) and 2.5 billion people at risk (Deubel and Rodhain 1999; Tolle 2009). This is primarily due to the vector of transmission, the 10 species of *Aedes* mosquitoes which transmit dengue to humans and which are difficult to control and restrict (Campbell-Lendrum and Reithinger 2002; Fontenille et al. 2010; Tolle 2009).

Out of the ten potential vectors, the main two species are *Ae. aegypti* and *Ae. albopictus*, both of which become adults after a very short aquatic (immature) cycle, lasting between 7 and 8 days in the case of the former species and between 7 and 9 days in the case of the latter. The life span for both species is around three weeks (Centers for Disease Control and Prevention 2012a; Centers for Disease Control and Prevention 2012b).

Adult *Ae. aegypti* tend to disperse on relatively short distances, generally lower than 300-400 meters, and may spend their lifetime in or around the houses where they emerge as adults. While studies found various flight ranges for *Aedes* mosquitoes (Harrington et al. 2005; Honório et al. 2003; Reiter et al. 1995), the general consensus is that adult *Aedes* mosquitoes tend to have a relatively limited flight area, compared to other species, irrespective of other factors, such as season or location (Harrington et al. 2005). Thus, using mark-release-recapture techniques, a maximum flight range

between 199 meters (Harrington et al. 2005) and 840 meters (Reiter et al. 1995) was recorded.

In Senegal, a highly anthropophilic domestic form of *Ae. aegypti* is present in sahelian villages and in urban area, colonizing artificial water containers and abandoned containers (Huber et al. 2008).

Dengue is caused by four related viruses of the *Flaviviridae* family, namely DENV 1-4 and infection with one type leads to immunity to that type, but not to the other ones (Bourgeade and Marchou 2003; Demanou et al. 2014). It has an incubation period of 3 to 14 days, after which the patient experiences a sudden onset of fever. This is, often, the only detectable symptom of dengue, especially in the case of younger children (Tolle 2009). While most infections cause only mild symptoms and dengue is generally a self-limiting disease, up to half a million cases worldwide (from a total of 50 to 100 million cases) degenerate into an acute form – the dengue hemorrhagic fever and the dengue shock syndrome – which involve distinct symptoms and have a high fatality rate (Tolle 2009).

Studies and Advancements

Both dengue fever and dengue hemorrhagic fever are prevalent in urban areas (Weiss and McMichael 2004). This is due primarily to the good adaptation of its vector to modern human life: the *Aedes* mosquitoes are antropophilic, preferring to feed almost exclusively on human blood (Hayden et al. 2010; Vanwambeke et al. 2006); also, *Aedes* female mosquitoes often choose manmade water bodies for oviposition (de Mattos Almeida et al. 2007; Hayden et al. 2010; Tolle 2009). Egg production sites are usually within or in close proximity to households and their flight span is short, which means that *Aedes* mosquitoes tend to breed and live close to households (Centers for Disease Control and Prevention 2012b).

Given that *Aedes* mosquitoes are active during day-time and have a preference for resting indoors, certain preventive measures such as sleeping under bed nets are rendered inefficient (Dieng et al. 2012; Pages et al. 2008). Moreover, recent studies from the past 15 years have indicated increasing resistance of *Ae. aegypti* populations to commonly used insecticides, due to the intensive use of these compounds (Badolo et al. 2019).

The existence of dengue in Africa has been scientifically documented since 1956, when a retrospective serosurvey confirmed a past epidemic in South Africa in 1926-1927 (M. Diallo, Ba, Sall, et al. 2003). However, in Africa, large dengue epidemics have rarely been reported, compared to Asia, America or the Pacific regions (Demanou et al. 2014). Therefore, still relatively little is known about the prevalence and burden of dengue in Africa, when compared to the Asian continent, in spite of recent resurgences (Demanou et al. 2014; Gubler 2004; Ridde et al. 2016). In Senegal, although poorly documented, dengue is thought to have a low prevalence and studies tend to confirm a general low susceptibility of mosquito populations (M. Diallo, Ba, Faye, et al. 2008). One notable exception was an epidemic during September and December of 2009, including 193 laboratory-confirmed cases in Dakar (Faye et al. 2014).

Chikungunya

Definition, Pathogens and Transmission

Chikungunya was first discovered in Eastern Africa in the 1950s (Her et al. 2009; Ng and Hapuarachchi 2010; Pérez Sánchez et al. 2014). Its name means “that which bends up”, referring to the painful and incapacitating joint pain caused by the disease (Chevillon et al. 2008; Pialoux et al. 2007; Tolle 2009).

As with dengue, chikungunya is primarily transmitted to humans by means of infective bites from certain species of *Aedes* mosquitoes, usually *Ae. albopictus* and *Ae. aegypti* (Centers for Disease Control and Prevention 2012c; Chevillon et al. 2008; M. Diallo, Thonnon, et al. 1999). The disease has a relatively short incubation period, on average between 3 and 7 days (although the range is between 2 and 12 days), after which an abrupt onset of fever is experienced, together with powerful arthralgia (Pérez Sánchez et al. 2014).

Chikungunya is caused by the homonymous virus (CHIKV), a member of the *Alphavirus* genus, of the *Togaviridae* family (Pérez Sánchez et al. 2014). Currently, there is no antiviral treatment for chikungunya infections and medical care consists of symptom management, i.e. control of fever and of arthralgia (WHO 2017a).

Studies and Advancements

Since the disease has been first identified in Tanzania in 1952/1953, chikungunya outbreaks have been relatively less documented, compared to, for example, yellow fever outbreaks. This is due to the fact that chikungunya cases are generally sporadic and affect small numbers of people (Chevillon et al. 2008; Pérez Sánchez et al. 2014; Tolle 2009).

Chikungunya epidemics are characterized by long inter-epidemic periods and have been reported every 4-5 decades (Halstead, 2009, cited by Ng and Hapuarachchi 2010). The epidemics usually affected tens of thousands of people, but reaching up to hundreds of thousands and even to more than one million of cases (Ng and Hapuarachchi 2010), although with low mortality and rarely degenerating into severe cases (Her et al. 2009; Tolle 2009). At the same time however, sustained epidemics have made millions of victims in recent years, particularly in countries from East Africa and South Asia (Tolle 2009). Despite its re-emergence in Sub-Saharan Africa since 2004 (Seyler et al. 2009), the disease has been generally ignored in scientific literature, except when it caused important outbreaks (Chevillon et al. 2008). For example, an outbreak of the disease, transmitted by *Ae. aegypti* in Senegal in 1996-1997, resulted in a 35% seroprevalence (Manore et al. 2014). However, few chikungunya epidemics have been reported in Senegal, most of them transmitted by *Ae. aegypti* (M. Diallo, Thonnon, et al. 1999).

Diagnostic of chikungunya is sometimes hampered by the fact that symptoms are generally similar to those of dengue (Organización Panamericana de la Salud and WHO 2014; Tolle 2009). Although differential diagnosis is possible via serologic examination, it is not as widely available as for other flaviruses (Tolle 2009).

Yellow Fever

There are very few cases of yellow fever in Senegal (WHO 2011), therefore I will not include yellow fever among the disease descriptions presented here. However, given that yellow fever is transmitted by the same mosquitoes that transmit dengue and chikungunya (species of the *Aedes* genus), the same general risk factors apply to yellow fever, as to dengue and chikungunya.

4.2 Risk Factors and Protective Factors

Diseases in general, and infectious diseases in particular, are generally the result of the association between three factors: the pathogen, the host and the environment (Engering et al. 2013). Therefore, they can be studied within the so-called “disease triangle” paradigm (See Figure 4.1), used to predict epidemiological outcomes in public health. It illustrates the interactions between the three components: an infectious agent, a vulnerable host and an environment which favors the infection:

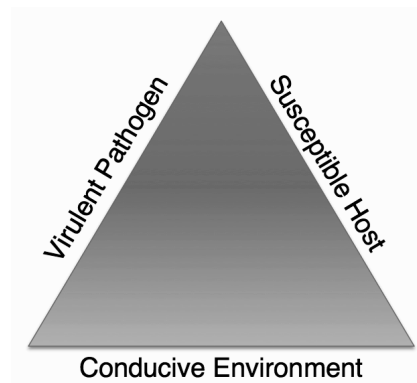


Figure 4.1: The Disease Triangle

Adapted from Scholthof 2006

However, until relatively recently, research has mostly focused on the relationship between the first two factors (Mauny et al. 2004), since the primary means to define any disease is by naming a pathogen or agent that negatively affects the health of the host organism (Scholthof 2006). Although less often studied, the environment bears a significant role in the transmission of infectious diseases. The current research aims to, not only take that into consideration, but give it a special place and focus on the potentially deleterious effects that the environment can play on human health.

Often, risk factors are similar in the case of febrile and diarrheal diseases, but their influence on transmission is different. In the case of diarrhea, infection usually occurs by water contaminated with feces,

while in the case of fever associated with vector-borne diseases, it occurs via a hematophagous arthropod, usually a female mosquito. However, certain individual characteristics and aspects related to the immediate environment (domestic and neighborhood) appear to have an impact on both the risk of diarrheal disease and the risk of vector-borne diseases. These factors can affect both exposure² and vulnerability³.

In the pages that follow, I will be analyzing existing literature on potential determinants of water-related diseases in children. In doing so, I will focus on the aspects which constitute the centerpoint of this study (the behavioral and the environmental spheres). Therefore, the amount and structure of the information I will present on each factor will correspond to its place in the study: for aspects which do not constitute the focus of my study, the information will be more succinct, whereas the focal points of the thesis will be presented more in depth. For these focal points I will follow a structure of 1) Context and Mechanism of Action of the potential determinant, 2) Research and Measurement Challenges of its analysis and 3) Debate in the existing literature on the topic. A synthetic table of this literature review is available in Annex A.

4.2.1 Demographic and Biological Factors

These determinants are characteristic to each individual and they can depend on biological characteristics or on socio-cultural factors and the conduct of the parents. Since they do not constitute variables of interest and will only constitute potential control variables in the current research, I will briefly present the impact (be it positive or negative) that literature in general has found them to have on the water-borne diseases considered here.

Age

Age often modulates both an individual's exposure to potential diseases, as well as his/her vulnerability. Especially in the case of

²By "exposure" I am referring to a specific eye, mouth, other mucous membrane, skin or parenteral contact with pathogens

³By "vulnerability" I am referring to an individual's susceptibility of becoming sick, compared to another individual and given a certain level of exposure

infectious diseases in children, being of older age is often considered to protect against illness twofold.

On the one hand, the immune system is comprised of two components: the innate immune system and the adaptative immune system. The first one provides an early first line of defence against pathogens, but it is almost latent or very weak at birth, and slowly develops with age (Simon et al. 2015). The adaptative immune system consists primarily of T-cells (which develop in the thymus) and B-cells (which occur in secondary lymphoid organs and in the bone marrow) and, in newborns and young children, it is characterized by a tolerant receptivity and largely poor and incomplete antigen responses, when compared to older children and adults (Simon et al. 2015). These two aspects make the young child more vulnerable to most pathogens, even as both the innate and the adaptative immune systems start to develop.

On the other hand, exposure to potential pathogens also evolves with age. Younger children, especially before becoming proficient at walking, tend to crawl and are generally less capable of protecting themselves from dirt and mosquitoes than their older counterparts. In developing countries, young children are particularly at risk, since they often crawl and play in areas where they are likely to encounter feces-contaminated soil. This happens most often by means of other individuals or animals that happened to tread in feces elsewhere and subsequently bring the pathogens into the vicinity of the infant or toddler (Ngure et al. 2013). In addition, infants and toddlers experience typical hand-to-mouth behavior as part of their normal development, which renders them more at risk of becoming infected than older children (Ngure et al. 2013; Shope 2014). This protective role of age usually stays true for both diarrheal and vector-borne diseases and thus, older children tend to be less prone to disease than their younger counterparts (Kandala, Magadi, et al. 2006; Mauny et al. 2004; Monteverde et al. 2010; Thang et al. 2008).

Using Multiple Indicator Cluster Surveys (MICS) II data in 2000 in Sudan, Siziya and colleagues (2013) find that younger age categories were generally associated with increased diarrheal infection in children. Similarly and also using MICS II data, for the Democratic Republic of Congo in 2001, Kandala and colleagues (2009)

find an increase in both diarrheas and fevers with the child's age, up to around one year old, followed by a steady decline afterwards. Also regarding the co-morbidity of diarrheal and febrile episodes in children, both using Demographic and Health Surveys (DHS), Yadav and colleagues (2017) for India in 2005-2006 and Kazembe and Namangale (2007) for Malawi in 2000 find that, past infancy, a steady decline in the risk of co-occurrence remains stable, up to 59 months (just under five years). However, both MICS surveys (developed by the United Nations Children's Fund (UNICEF)) and DHS are conceived in a similar manner and are in many aspects comparable to each other. Therefore, with MICS data as with DHS data, in the aforementioned studies the cutoff point for the child's age is just under 5 years old.

Along the same line of age-related protection, Imbert and colleagues (1997), conducted a retrospective study between 1990 and 1996 on 472 children aged up to 15 from Dakar, using positive malaria smears and severe anemia as main presentation of severe malaria. The authors found that the risk of severe anemia was significantly and negatively associated with age, especially in cases with hyperparasitemia (high density of the parasite in the blood).

Given the important role of age on both vulnerability and exposure to disease in general, I will include the age of children, in a continuous form ⁴, in the current study, as a control variable.

Sex and gender

The terms "sex" and "gender", although often used together, refer to potentially different aspects: whereas generally by "sex" we refer to differences, between male and female organisms, that are primarily biological in origin, we use the term "gender" to denote differences which spawn from social or cultural perceptions and practices regarding the sexes. This is because although women and men differ on a biological level, it is often the roles that society assigns to them and the traits it encourages in them, which influence their risk factors and exposure.

⁴Given that data are available at a fine level (in years of age), it makes the most sense to use this. However, models using age groups of children will also be tested

Both sex as a biological concept and gender as a social construct can, independently of other factors, determine differentials in the burden of disease (Krieger 2003, cited by Buvinić et al. 2006). However, there is generally little consensus in existing literature as to who, between males and females, experiences higher risks for disease. Part of the literature states it is generally accepted fact that, while having a higher life expectancy, women tend to experience an overall higher morbidity (Buvinić et al. 2006). Contrarily, another part of literature states the exact opposite, that both mortality and morbidity are higher for males than females, and that this happens throughout life (Lozano et al., 2012, cited by Muenchhoff and Goulder 2014). Some authors have brought forth a theory of gendered immunodeficiency in children with regard to infectious diseases. This stipulates that male children, especially below the age of four, tend to have an excess incidence in infectious diseases (Green 1992).

In many cases, the situation is further complicated by socio-cultural aspects related to gender differentials in health-related behavior, healthcare offer and demand. For example, in some cultures little girls are less well cared-for in case of illness than little boys. For example, girls may be less often brought to healthcare providers than boys or the time lapse between the onset of symptoms and hospital admission may be longer (Mitra et al. 2000). This leads to increased risk of severe forms of infection and potentially of death (Mitra et al. 2000; WHO 2007).

In terms of water-borne infections, both the biological and the social aspects – meaning both sex and gender – may come into play, and gender differentials in young children tend to be lower. For example, a large-scale study in Sudan, focusing on diarrheal episodes in children aged 5 or less and using data from the Sudan MICS II, found a very low gender differential in terms of odds. Thus, boys were found to have very slightly higher odds ($OR = 1.03$, $p=0.044$) of diarrheal prevalence compared to girls. (Siziya et al. 2013). Also using MICS II data, for the Democratic Republic of Congo in 2001, Kandala and colleagues (2009) find no impact of the child’s sex on the odds of either diarrheas or fevers in children under five.

Similarly, a study on six Asian countries found some gender differentials when looking at reported dengue cases, but which only

concerned individuals over 15 years old (Anker and Arima 2011). For children aged 1 to 4 years and 5 to 14 years, gender differentials were not consistent and the magnitude of the difference was very small ⁵ (Anker and Arima 2011).

Thus, although literature regarding the role of gender and sex on infectious diseases tends to not point towards major differences in children, given the general importance of sex and gender on health in general, it will be included in the current research as a dichotomic control variable, with data collected in terms of the child's sex.

Breastfeeding Status

The impact of breastfeeding on water-borne diseases depends both on the type of infection and on the age of the child.

With regard to diarrheal diseases and in young children, breastfeeding is generally known to have a protective role, reducing the risk of disease and of mortality from the disease (Mané et al. 2006; Mosley 1984). However, when prolonged after infancy (past the age of 12 months), breastfeeding has been found by most cross-sectional community studies in developing countries to be associated with lower weight-for-age, height-for-age and weight-for-height, as well with a lower nutritional status (K. B. Simondon and F. Simondon 1998). This, in turn, makes the child more vulnerable when confronted with diarrheal pathogens. However, past the age of introduction of additional foodstuffs, the confounding impact of these additional foodstuffs may come into play. For example, Simondon and Simondon (1998) found that none of the Senegalese infants they studied were exclusively breastfed, since they were also given water. Moreover, the authors found that generally, the introduction of additional food happened too early and that more than a quarter of infants were given additional food before the age of four months (K. B. Simondon and F. Simondon 1995).

As for mosquito-borne diseases, the impact of breastfeeding tends to be less clear-cut. For example, in children aged 6 to 15 months and 15 to 24 months exposed to HIV, a study in rural Uganda found that being breastfed reduced the relative risk of a malarial episode

⁵Moreover, the study focused only on cases reported, which could also bring into discussion possible gender differentials in (adult) health reporting.

(Vora et al. 2010). However in children unexposed to HIV, the same study found no conclusive impact on the risk of malaria incidence, as the relative risk of breastfed children was slightly higher, but the result did not attain statistical significance.

This being said, while the vast majority of children are ever breastfed in Senegal (Gartner et al. 2007), breastfeeding practices differ significantly between urban and rural areas. While extended breastfeeding tends to be rather common in villages (K. B. Simondon and F. Simondon 1998), urbanization has led to a general decrease in both the prevalence and the duration of breastfeeding in Sub-Saharan Africa (Mané et al. 2006). Thus, children in urban Senegal are generally not breastfed beyond the age of two, with over 90% of children aged 24 to 35 months not breastfed (anymore) (Gartner et al. 2007).

Therefore – given the lack of discriminatory value of the variable in urban Senegal for children aged two or above and also given the lack of availability of information on breastfeeding in the database used – the breastfeeding status will not be included in this research.

Mother's age

Regarding the age of the primary carer (most often mothers), the most noteworthy aspect in existing literature involves young and very young carers. This is because young age has been consistently associated with lower levels of knowledge regarding child health and development, even after controlling for socio-economic factors (Tamis-Lemonda et al. 2002).

However, when looking strictly at its role in water-related diseases, results seem somewhat less clear-cut. Data from the Kenya 2008-2009 DHS yielded a significant association between maternal age and childhood diarrhea, with teenage mothers having the highest risk (Mbugua et al. 2014). Similarly and also using age categories on the 2009 Malawi DHS, Kazembe and colleagues (2009) found that children of mothers aged under 22 years had increased odds of fever and of diarrhea (Kazembe, Muula, et al. 2009).

Also in Malawi and with DHS data, but from 2006 and using bivariate analysis, Kandala and colleagues (2006), found a different pattern, namely that the influence of the mother's age on diarrhea

and fever was nonlinear, but with a slight general tendency to decline (which, however, was deemed less reliable, due to the small number of observations at older ages of the mother).

However, looking at the relationship between the mother's age and her knowledge about diarrheal disease, its prevention and treatment, Ansari and colleagues (2011) found no significant association, using data from a survey done between June and August of 2010 in a disadvantaged community from Nepal. Similarly, regarding knowledge about child health, Al Ayed (2010) found no relationship with maternal age in a study from Saudi Arabia.

Given its potential impact on health-related conduct, the primary carer's age will be included in the statistical models, as control variable.

4.2.2 Socio-economic Factors

Most behavioral (and environmental) determinants depend, at least partially, by certain socio-economic traits, most notably education and wealth of the primary carer (generally the child's mother) or of the family. These influence, to a large extent, the will and capacity of individuals and households to protect themselves and their offspring from potential diseases. Most often, they work by constraining families in the use of new practices and technologies (Mosley 1984). Since education, occupation and wealth do not constitute variables of interest in the current research and will only constitute potential control variables, I will briefly present their general role on the water-borne diseases in question.

Education of The Primary Carer

Education constitutes one of the major protection factors for individual health, being associated with better overall health and lower mortality (Palloni 2006). In the case of children, it is usually the parents' (mother's or father's) education which plays the most important role (Filmer 2005).

Often, fathers' education strongly correlates with occupation and income and therefore, the relationship it has with the child's health status is, to some extent, shaped by the effect of income (Mosley and Chen 1984). However, the situation is different for mothers and

the mother's education has, in the past fifty years, been increasingly associated with child health, more so than the father's education or occupation (Cochrane et al. 1982; Hobcraft 1993). When looking particularly at the link between maternal education and the child's survival, several causal pathways have been suggested (Caldwell (1979) and Lindenbaum (1990), cited by Hobcraft 1993):

- through education, women have more negotiation power in the household, and thus greater control over health decisions regarding the children
- educated women have increased capacities in interacting with medical personnel and understanding medical posology
- education leads to a shift from the 'fatalistic' acceptance of health outcomes towards active measures to preserve health
- educated women tend to put more weight on aspects related to hygiene and health preservation
- educated women tend to marry later and to have their first births later, generally past teenage years

With regard to the potential impact of the mother's education on water-related infections, studies have found that in most contexts, the relationship tends to be negative (A. Diallo, Dos Santos, et al. 2012; George et al. 2014; Krefis et al. 2010). However, the differentials are generally significant only when considering secondary and higher education. For example, Mbugua and colleagues (2014), looking at diarrheal episodes in children under five and using the 2008-2009 Kenya DHS, found that only having a mother with higher education significantly protected the child from diarrhea, compared to having a mother with no education, whereas the primary and secondary levels did not lead to a significant reduction in the odds of disease⁶. A study done also in Kenya found that the propensity to purchase mosquito nets from the retail sector was increased with education, but only for levels secondary or above (Noor et al. 2006).

That being said, in some Sub-Saharan African contexts, the pro-

⁶It is to be noted that in the ACTU-PALU sample, only 105 (2.5%) of primary carers had post-secondary education

protective role of maternal education tends to be less marked than on other continents. For example, a study using the DHS data of 23 countries from Africa, Asia and Latin America, found that the prevalence of diarrhea was significantly higher in children of uneducated women, compared to children whose mothers had primary schooling; however, this relationship was reversed in four Sub-Saharan African countries (Boerma, Sommerfelt and Rutstein, 1991, cited by Hobcraft 1993). Also, Koram and colleagues (1995a), in a case-control study from Gambia, found no significant relationship between the education levels of mothers whose children had experienced severe or mild malaria.

Several factors have been hypothesized to come into play in this relationship (Hobcraft 1993). Among them, the relatively higher levels of labour migration and child fostering. In some cases, these childcare practices may interact with the mother's education, leading to situations where the children of women with a higher level of education may be at higher risk of child death than the children of uneducated mothers. Moreover, poorer Sub-Saharan African contexts may be lacking in terms of health infrastructures, which inhibits the ability of more educated women to use their human capital for preserving the health of their children.

These hypotheses may offer, at least partially, an explanation as to why a significant number of studies find no consistent relationship with infectious diseases, or even find slightly elevated risks for children belonging to mothers who are educated. For example, looking at the determinants of malaria in children under-five with data from the 2008 DHS in Ghana, Nyarko and Cobblah (2014) found an increase of 15% to 29% in the odds of a malarial episode if the mother was educated (primary, secondary and higher education each), compared to if she had no education, a finding which is contrary to the theory of a protective role of the mothers' education. However, since the association did not reach a 5% level of statistical significance, the authors did not advance hypotheses as to why this association was observed in their study. Similarly, using the 2000 Malawi DHS dataset, Kandala and colleagues (2006) find a slightly increased risk of fevers for children of mothers with primary education, compared to those with no education. Although observed for both incomplete primary and complete primary lev-

els and statistically significant in the first case, the authors do not further develop the aspect.

Looking at diarrheal infections, Siziya and colleagues (2013) found no relationship with the mother's level of formal education in a study using the 2000 MICS II data from Sudan. Studying diarrheal disease of staphylococcal origin in a meta-analysis of six peer-reviewed researches, Einstein and colleagues (2017) also did not find a significant impact of the mother's education.

Another aspect to be noted is that of controlling for other socio-economic aspects, as well as for behavioral factors. For example, when accounting for maternal endowment (behavior and health status related to childhood family background), the effect of maternal education on child health and nutrition disappeared in a study on Nicaraguan women (Behrman and Wolfe 1987).

And finally, differences in the pattern of association between the mother's education and disease may reflect – among others – differing propensities to report diarrheal disease, given the often self-selective nature of reporting (Filmer 2005), potentially confounding factors or real differentials in incidence (Hobcraft 1993). Other studies have mentioned interactions regarding education, whereby maternal education's protective role disappears in more disadvantaged communities or is significantly diminished in the wealthier households (Dargent-Molina et al. 1994). This would imply that only increasing maternal education, in itself, may not necessarily have a marked beneficial effect on child health, in the absence of basic community infrastructures. Similarly, in the wealthiest households, the impact of an increase in the mother's education may not have a significant added value, given the already increased baseline level.

Thus, there is evidence of improved health for children born to women who are educated, although there are some studies mention a decreased impact, most notably in certain Sub-Saharan African countries (Hobcraft 1993).

Occupation of the primary carer

With regard to the occupation of the child's primary carer, by and large, literature focuses the effects concerning the mother and

generally compares housewives/stay-at-home mothers to those who work. Results obtained tend to be somewhat mixed and, while in some studies children of mothers who work are advantaged, in others it is the opposite.

Using bivariate analyses on data from the Indian National Family Health Survey (NFHS-3) of 2005-2006, Elizabeth and Raj (2012) did not find a significant association between the mother's occupation and diarrhea in children under five. However, the study did find that children whose mothers were housewives had a significantly lower prevalence of fevers. Contrarily, a logistic regression with data from a cross-sectional survey done in 2014 in Mbour (Senegal) yielded a significant association between diarrhea in children under five and the mother's occupation. Thus, children whose mothers were housewives had significantly higher odds of diarrheal disease than children of mothers working in the private or public sectors (Thiam et al. 2017). Inversely, a study using 2011 DHS data regarding diarrhea in Ethiopian children and comparing strictly women who work to those who do not, found increased odds of disease when the mother worked, as opposed to being a housewife (Mihrete et al. 2014).

From a slightly different perspective, looking at knowledge regarding the home management of diarrhea among caregivers of children under-five from Ethiopia, a 2017 study by Desta and colleagues (2017) found that women doing odd jobs were less likely to be knowledgeable and have medically appropriate practices concerning diarrheal disease in children.

Family wealth

Household wealth is usually considered as a protective factor against childhood disease, because it enables families to adopt a more health-preserving conduct and to use the newer technologies available (Mosley and Chen 1984; Thang et al. 2008; Woldemicael 2001). Looking at child health in general, Palloni (2006) found that investigating household wealth leads to steeper differences than parental education, on long term individual health.

Along this line of thought, most existing studies report negative links between wealth and water-related diseases. For example, using Nigeria's 2008 DHS data in a two-level logistic regression, Yusuf

and colleagues (2010) found that the prevalence of fevers was highest among children from the poorest households. Using ownership of a television as proxy for wealth in a cross sectional 2006–2007 survey, Demanou and colleagues (2014) find an increased risk of sero-epidemiologic dengue in Garoua, Cameroon, associated with not having a TV-set.

However, some studies report no significant association between wealth and water-related diseases: for example, Ghana’s 2008 DHS data yielded no significant relationship, in multivariate models, between wealth and malaria in children under five (Nyarko and Cobblah 2014). In two different studies, one pooling the 1999 and the 2003 DHS data from Nigeria and the second one using the 2001 MICS II data from the Democratic Republic of the Congo (DRC) and using multivariate analyses, no relationship between either diarrhea or fever was established using the Nigerian sample, but a significant relationship was established concerning diarrhea, using the DRC one (Kandala, Emina, et al. 2009; Kandala, Ji, et al. 2007).

In a study from Central Vietnam, Thang and colleagues (2008) combined logistic regression with a classification tree model (CART) on blood samples for *Plasmodium* infection, which showed that the most important risk factor for malaria was wealth, the wealthiest group being much less infected than the lower and average wealth category. However, they found no significant difference between the latter two categories, in terms of malarial infection. This also draws attention to the threshold of wealth necessary for a significant difference in terms of health outcomes.

Another aspect to be noted is that, while wealth is generally considered to play a protective role, the manner of measuring wealth has often been the subject of debate (Howe et al. 2008). Indicators for measuring wealth are very diverse and the referent may be either the mother, the father or the household (Palloni 2006). When referring to either the mother or the father, financial resources are usually measured by means of income, whereas when referring to the household as a unit, classic approaches typically either use household expenses or income as indicators. However, in most developing countries, collecting information on income and expenses proves difficult, given the relatively high prevalence of in-

formal economic activity (be it revenue or consumption) (Kobiané 2003).

Therefore, newer approaches have shifted towards collecting data on alternative indicators referring to the households's possession of long-term goods (durables), other assets and construction characteristics (Filmer and Pritchett 2001). These approaches generally use a dimension reduction method, such as Principal Component Analysis (PCA) or Multiple Correspondence Analysis (MCA) to group the indicators into a more general sphere of household wealth, which would, in turn, approximate prosperity and economic resources, in a more easily available and less bias-prone manner (Córdova 2009; Kobiané 2003; Traissac and Martin-Prevel 2012).

4.2.3 Health-related Knowledge and Behaviors

Most types of individual action regarding health can be brought together under the broad concept of health literacy, or “the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways which promote and maintain good health” (Nutbeam, 1998 cited by Nutbeam 2000, p. 264).

Certain types of behavior related to health literacy, particularly in terms of personal hygiene (in the case of diarrhea) and of preventing the access of the vector inside the compound or to potentially infective bites, can influence exposure to pathogens responsible for water-related diseases. These behavioral aspects become particularly important in the case of highly endemic environments, where better health literacy leads to improved outcomes in terms of infectious diseases, depending on the individual's cognitive and social skills.

While certain actions can be measured at individual level (such as handwashing), others pertain to the household as a whole and affect most (if not all) its members. Thus, for example failing to mosquito-proof a part of the compound can have a negative impact on all members of the household.

Protection against Mosquitoes

Insecticides and repellents

Context and Mechanism of Action

Various types of repellents (such as coils or sprays) have been proved effective in keeping mosquitoes at bay from human blood meals (V. Robert et al. 2003), since they shorten the lifespan of mosquitoes, thus preventing further mosquito-borne infections (Sullivan 2010; Tolle 2009).

Research and Measurement Challenges

Although the role of insecticides and repellents in either killing or driving mosquitoes away from the compound is quite clear, their role in reducing vector-borne diseases is difficult to assess, since most of them require constant application in order to be effective. This raises a question of compliance, which varies across cultural contexts, levels of education and economic situations.

Moreover, several actions considered until recently as key factors in reducing the burden of mosquito-borne diseases (most notably of malaria) are now becoming increasingly less effective. Among these actions is indoor residual spraying, due to a recent and rapid development and spread of resistance to widely used insecticides (Keiser et al. 2005).

Another noteworthy aspect, albeit literature is particularly scarce, is that of the possible relationship between the use of bed nets and the vector density in the area (Thomson et al. 1994). Thus, Thomson and colleagues observed a reverse in the relationship between bed net use and malaria, which they attribute to a higher propensity to use bed nets where mosquito densities are higher.

Debate

Comparing severe malaria cases to community controls, Snow and colleagues (1998) found a twofold increase in risk of developing a severe malaria case (as opposed to not being infected), when no repellents (such as aerosol, mosquito coils or local repellents) were used in the room of the child.

DDT spraying status was associated with a significant decrease in the risk of *Plasmodium* infections in a Madagascar-based study (Mauny et al. 2004). Moreover, the protective role of DDT was

found to be greater for children less than 10 years old, than for the older subjects. Spraying the house with aerosols or DDT was also found to diminish the risk of malaria-related febrile illness in children from the Adami Tulu district in Ethiopia (Deressa et al. 2007).

The same practice was found to be a protective factor against malaria in a univariate analysis on data collected from cases and healthy controls in a peri-urban area of The Gambia (Koram et al. 1995b), but the association lost its statistical significance when controlling for other factors. In another study comparing mild and severe malaria cases, the same authors found no significant relationship, in a multivariate model, between the use of mosquito coils and the risk of developing severe malaria (as opposed to mild cases), despite association in univariate analysis (Koram et al. 1995a). However, the authors did not set forth further hypotheses regarding this finding.

Neither did Konradsen and colleagues (Konradsen et al. 2003) in a rural dry zone of Sri Lanka, nor Guthmann and colleagues (Guthmann et al. 2001) in the low-transmission area of Grau (Peru) obtain significant effects of household protective measures. However, the former analyzed the role of mosquito coils and traditional fumigants on the presence of two species of *Anopheles* in compounds (Konradsen et al. 2003). While being a possible proxy for infective bites, it does not necessarily imply malarial infection. Also, the authors stated that both the use of traditional fumigants and of mosquito coils was not followed continuously throughout the study period, which could alter the reliability of the collected data (Konradsen et al. 2003). In the second case, the lack of a significant relation with spraying status may also be due to the extremely small number of cases and controls living in houses that had been sprayed in the previous 6 months (7 cases and 31 controls, as opposed to 315 cases and 937 controls living in houses that had not been sprayed).

In this context, the use of insecticides (as spray, incense or coils) will be included in the current research, as category of a variable measuring protection against mosquitoes.

Bed nets

Context and Mechanism of Action

The use of bed nets has been among the most studied methods for malaria prevention, since the end of the 19th century (S. W. Lindsay, Emerson, et al. 2002) and its efficiency in preventing *Plasmodium* infections has been recently confirmed by several studies (de Mattos Almeida et al. 2007). However, bed nets – while being particularly useful against malaria transmission – are significantly less useful against dengue, since *Aedes* mosquitoes tend to bite during the day (Pages et al. 2008; Sullivan 2010).

Among bed nets, the most efficient are considered to be insecticide-treated net (ITN) and especially long-lasting insecticide-treated net (LLITN), which function as a trap (Noor et al., 2007, cited by Tolle 2009). They thus shorten the lifespan/longevity of the mosquito which rests on them, preventing further infestation (Killeen et al. 2002; Sullivan 2010). This being said, bed nets in general constitute a powerful mechanical barrier (and chemical as well, in the case of ITN) against mosquitoes.

Research and Measurement Challenges

As with insecticides, the effectiveness of bed nets resides in consistent use. Lifestyle and community or household habits may affect their efficiency: if individuals typically stay outside later in the evenings and are therefore exposed to infective bites or if a part of household members do not sleep under the bed net ⁷, the protective effect of bed nets is significantly reduced (V. Robert et al. 2003).

Also, even untreated bed nets have a protective role against malaria, but only if they are in good condition (Clarke et al. 2002). Therefore, damaged mosquito nets or nets that have been also used for other purposes than mosquito-protection (for example as fishing nets (Minakawa et al. 2008)), may offer little to no protection. Hence, misuse or even failure to treat bed nets regularly can diminish their protective function (Clarke et al. 2002; Iwashita et al. 2010; Jima et al. 2010; Minakawa et al. 2008), but these aspects are difficult to assess in studies. For example, the DHS programme

⁷Reasons for non-use are varied and the most cited refer to excessive heat under the bed net, the perceived lack of mosquitoes or the disruption of sleeping arrangements (Alaii et al. 2003)

focuses on household possession, the type of bed net and whether or not the child has slept under one in the previous night, in order to estimate bed net usage (Ministère de la Santé, de la Prévention et de l'Hygiène Publique, Sénégal et al. 2009).

Moreover, bed nets are typically used at night and hence only protect against mosquitoes which bite during the night. As an anti-malarial protection method, bed nets are quite efficient, as *Anopheles* females tend to search for bloodmeals during night-time. For example, a study conducted in ten areas of Dakar found that the peak biting time was between 1:00 and 5:00 at night, both outdoors and indoors; however biting behavior was also registered earlier, especially indoors, where over 10% of bites happened before 23:00 (Machault et al. 2009). Similar results, obtained by Pagès and colleagues (2008) in a two-year study in Dakar, also suggest that bed nets do not offer full protection against malaria, given the biting pattern of *Anopheles*. And against dengue and chikungunya, the role of bed nets is even less pronounced, given that *Aedes* mosquitoes are known to bite during the day (Centers for Disease Control and Prevention 2012a).

Debate

In a coastal area of Benin, the odds of malarial infection were 0.79 (0.63 – 1.00 at 95% CI) lower in children who slept under a bed net, regardless of its type, compared to those who didn't (Nahum et al. 2010). In the towns of Mopti and Sevaré (Mali), child consultation rates for presumptive malaria decreased significantly after a bed net treatment kit intervention conducted in 2001 (Rose-Wood et al. 2010).

Similarly, a study in Eastern Uganda found that the risk of *Plasmodium* infection was significantly lower for children living in households equipped with a bed net that had been treated, as well as for children who had slept under a bed net in the previous night (Pullan et al. 2010). Also, fever-induced childhood mortality in general has decreased in most areas where children sleep under bed nets (Yusuf et al. 2010).

Other studies have found no statistically significant relationship between bed net use or possession and malaria. For example, a secondary analysis on the 2008 Nigeria DHS showed no association

(Yusuf et al. 2010). However, in this case bed net possession was low in general (Yusuf et al. 2010). In a case controlled study on children from the Kenyan coast, no statistically significant difference was observed between the children who had slept under an untreated bed net and those who hadn't, in terms of malaria (Snow et al. 1998). However, bed net usage in the area was again very low, both in terms of percentage and of absolute numbers. A similar limitation, in a study set in north-central Sri Lanka (Konradsen et al. 2003), yielded no statistical significance between bed net usage and *Anopheles* presence in the compound. Aside from this, none of the few bed nets used had been impregnated and the authors did not measure actual malaria, but only the presence of infective *Anopheles*.

The same issue of poor bed net condition appeared in the study of Guthmann and colleagues (2001), where no significant association between bed nets and malaria was observed. This being said, many of the study's subjects had declared that their bed nets were torn and had not been impregnated recently (Guthmann et al. 2001).

Another aspect to be taken into consideration is that of possible colinearity between bed net possession and socio-economic status. Although Matthys and colleagues (2006), found no relationship between *Pl. falciparum* infection and sleeping under an (impregnated) bed net, possession was, in this study, strongly correlated with socio-economic status, since less than 5% of the 139 individuals in the poorest quintile had a bed net, whereas in the richest quintile it was almost half (Matthys et al. 2006).

Therefore, the presence and usage patterns of bed nets will be included in the current research, as category of a variable measuring protection against mosquitoes.

Hygiene

Context and Mechanism of Action

Hygiene is often considered to play the decisive role in diarrheal disease (and to a much lesser extent, in mosquito-borne diseases), while environmental factors are considered to play a secondary or tertiary role (Bukonya and Nwokolo 1990; Myaux et al. 1997;

UNICEF and WHO 2009). Thus, at present, measures to combat diarrhea tend to focus on solutions in the domestic domain, including breastfeeding, handwashing and washing of fruit and vegetables (Rego et al. 2005).

Hygiene can be assessed at three levels of analysis:

- the individual
- food and water
- the compound

At the individual level, among regular showering, tooth-brushing and hand washing, it is the latter that has the biggest impact on diarrheal diseases, as it prevents ingestion of diarrhea-inducing pathogens (Fewtrell and Colford 2004). Hence, targeted campaigns often focus on regular handwashing, especially before preparing or eating food and after going to the toilet.

In terms of food and water, according to the WHO (1994), measures in developing countries can be grouped around six main areas :

- washing, peeling or cooking fruit and vegetables
- protecting foods from insects, rodents, germs and poisons
- storing food in proper conditions and eating it as soon as possible
- keeping cooking areas, food and water containers clean
- avoiding urinating or defecating near or in a source of drinking or bathing water
- keeping animals away from water collection areas
- treating water used for drinking (where necessary), storing it in a covered container
- washing hands with water and soap or ash before preparing food, eating or feeding little children

Research and Measurement Challenges

Although variables related to hygiene constitute a necessary aspect to analyze, in practice this proves to be somewhat difficult.

Firstly, self-reported hygiene practices, such as handwashing, risk a high degree of socially desirable response bias (Contzen et al. 2015). Also, if proxy variables are to be used, their correlation to actual behaviors in terms of hygiene is ambivalent. While it is widely recognized that education plays an important role in acquiring knowledge and practices about hygiene, it is debatable whether it is primarily formal education that is the determining factor or rather knowledge acquired through life experience and interactions (Jalan and Ravallion 2003).

Focused campaigns, such as handwashing or anti-mosquito campaigns may also influence individuals' knowledge. Secondly, it is debatable whether learning about hygiene actually translates directly into improved practices (Strauss and Thomas, 1995, cited by Dos Santos and LeGrand 2007). Despite the two aspects mentioned here, it is most often formal education which is used to approximate hygienic practices at individual level (Jalan and Ravallion 2003; Waddington et al. 2009).

Thirdly, not all hygiene interventions yield the same results. Certain studies show that a more focused approach, centered on hand washing, tends to be more effective than general hygiene education measures (Fewtrell and Colford 2004). Contrarily, Heller (Heller 1999) studied four practices in a study conducted in Betim, Brazil. The four practices considered were washing and disinfection of fruit and vegetables; care of drinking water; hand-washing before eating; and hand-washing after defecation. In the multivariate analysis however, only the first practice, of washing fruit and vegetables, showed a statistically significant relationship with diarrhea, the absence of the practice being associated with a relative risk of 2.87 (95 % CI: 1.61 – 5.10). The author explains the lack of statistical significance regarding the other three practices by the fact that food hygiene might be a surrogate for general household hygiene (Heller 1999)

And finally, in Sub-Saharan African contexts, adopting biomedically efficient hygiene practices may be tributary to living conditions, such as the absence of a centralized wastewater management system. In some situations, even though individuals may consider certain actions as deficient, lack of proper conditions may force them to adopt these actions nevertheless, leading to a discrepancy

between attitudes and behavior (Dos Santos 2011).

Debate

Irrespective of methodological divergences, evidence with regard to the beneficial role of hygiene in limiting diarrheal diseases is quite solid and consistent over time (Waddington et al. 2009). In a meta-analysis by Fewtrell and Colford (2004), actions such as hand washing decrease the relative risk of diarrheal disease by 42% in the more developed countries (95% CI: 0.476 – 0.712).

Also, concerning hand hygiene, Masangwi and colleagues (2009) found that hand washing under running water or individually in a basin, as opposed to using a cup to pour water from a container, was associated with decreased diarrheal disease in children under three from rural Malawi. Similarly, results from a survey involving over 13,000 children from rural India suggest that the benefits of improved hygiene are at least as large as those from improving drinking water (Borooah 2004). The authors also found that hand-washing was somewhat associated with the mother's ability to read and write, although in their study, the latter variable accounted for only 5% of the variability in the likelihood of young children having had a diarrheal episode. Similarly, in a survey conducted on mothers of children from a Palestinian refugee camp, intestinal parasite infection was significantly higher among families with poor cleanliness of households, by 39% (Abu Mourad 2004).

Regarding mosquito-borne infections, using a dichotomous variable for cleanliness of the compound in a matched case-control study, Koram and colleagues (1995b) found a statistically significant relationship (both in univariate and multivariate analyses) with clinical malaria in children. On the other hand though, Peterson and colleagues (2009) found no significant relation between house tidiness or the fact of having construction works in or near the compound and *Plasmodium* infection in children living in a highland region of Ethiopia. However, the association with tidiness (though not with the presence of construction works) was statistically significant in the case of adults. The authors interpreted this finding by the fact that children may tend to move more from one compound to another, to play or work, than adults do (Peterson et al. 2009).

Thus, although hygiene is sometimes regarded as fundamental, wa-

ter supply and/or sanitation measures are also to play any role in diarrhea reduction. While it is clear that hygiene is essential, some studies show that certain specific environmental variables play a very important role (Rego et al. 2005) and that community infrastructure can have a significant impact on diarrheal disease, even without any significant measures to promote hygiene behaviour changes within the household (Moraes et al. 2003).

Consequently, it seems important that, in a study aiming to provide a comprehensive image of causal factors for water-related infections, including both factors pertaining to knowledge, behavior and to the environment is necessary. Given that reliable hygiene information is notoriously difficult to collect and that data on hygiene practices is not available in the ACTU-PALU database, I will approximate hygiene by means of the health literacy of the mother or guardian.

Also, given the somewhat scarce literature regarding the impact of informal education on health-related behavior, a rather interesting aspect to study is that of the potential impact that social capital – especially that of the neighborhood – on health literacy. Some studies have suggested that higher levels of neighborhood social capital can somewhat favor health-protective conduct in individuals (Bender et al. 2015). Although the effect was not a strong one, this could mean that social relations in the community may constitute a fertile ground for boosting health literacy in the local population.

4.2.4 Environmental Factors

Certain features of the immediate environment (domestic and neighborhood) appear to have an impact on both the risk of diarrheal disease and on the risk of vector-borne diseases. Although the environmental risk factors are often similar in the case of febrile and diarrheal diseases, the mechanism by which they influence transmission is different. In the case of diarrhea, infection usually occurs by water contaminated with feces, while in the case of fever associated with vector-borne diseases, it occurs via a hematophagous arthropod, usually a female mosquito.

Aspects like access to clean water, sanitation and hygiene (particu-

larly the understanding of the manner in which infections are transmitted) are considered to be key factors in preventing water-related diseases, by providing barriers to transmission (Waddington et al. 2009; WHO 2013a). However, worldwide around 1.8 billion people use a source of drinking water that has some degree of faecal contamination (UNICEF and WHO 2014). Similarly, around 2.5 billion people lack sanitation and, in developing countries, around 1.3 billion individuals practice indiscriminate or open defecation (Okullo et al. 2017; WHO 2017b).

This being said, there are many other environmental risk factors – more often documented for diarrhea – which have been reported to have an impact on water-related diseases, some of them accentuated in urban slums (Bukenya and Nwokolo 1990; Girma et al. 2008; Woldemicael 2001). This status quo creates further inequity between categories of population living in the same larger area. Hence, within the same country – or even the same city – cases are repeatedly reported in the same areas, indicating a relatively high level of clustering of the diseases (Myaux et al. 1997). However, assessing this clustering of infectious diseases within the same urban area is often deterred either by the high costs associated with large-scale studies which would map the occurrence of cases or with bias induced by the use of aggregated data, which impedes any conclusions and causal inference regarding the individual, on the basis of observations of groups (Morgenstern 1982). Also, the results of such analyses are not comparable with individual-level research, since the errors and sources of bias are not the same.

Domestic Environment

Several aspects of the domestic environment, especially related to sanitation, may play a role in water-related disease transmission. For example, the type of water source may act on both diarrheal and mosquito-borne infections: on the one hand, not having easy access to an improved source of water often leads households to store water inside or around the compound. However, water stored for long periods of time incurs a higher risk of contamination and therefore may favor diarrheal infections (Fewtrell and Colford 2004). On the other hand, if the storage method is not properly covered at all times, the containers can become breeding grounds for mosquitoes

and hence, put the inhabitants of these households at higher risk of contact with the vector. This would imply that children living in households without piped water are potentially more exposed to mosquito-borne febrile illnesses as well.

Wastewater management amenities in the household may also affect both types of pathologies. The type of toilet bowl and water tank can promote mosquito breeding and thus the risk of mosquito-borne diseases (Tsuzuki et al. 2009). Similarly, it is generally considered that inadequate sanitation constitutes a major risk for diarrhea, by facilitating contamination with feces (Fewtrell and Colford 2004). Other relevant features of the domestic environment include garbage storage inside or around the compound (both in terms of duration and in terms of container used), as well as certain features of the building, which can facilitate (or prevent) the access of mosquitoes, and thus their contact with humans.

Access to water

Context and Mechanism of Action

Worldwide, close to one billion people lack access to improved water, with high heterogeneity across the globe, in terms of coverage (Fewtrell and Colford 2004; UNICEF and WHO 2014). However, household access to safe drinking water is, together with educating the population towards good hygiene practices, considered to be a key component in preventing diarrhea (UNICEF and WHO 2009) and mortality in children in general (Howard and Bartram, 2003, cited by Dos Santos and LeGrand 2007). The historical argument in its favor is the fundamental role that piped water had in the sanitary revolution of Western cities in the 19th and beginning of the 20th centuries (Dos Santos and LeGrand 2007; Fewtrell and Colford 2004).

Moreover, irregular water supply means that families are forced to store water inside or around the compound for longer periods of time, for drinking or cleaning purposes and the recipients used may, especially if not properly airtight, become breeding sites for mosquitoes (Braga et al. 2010; Ridde et al. 2016). Therefore, the presence of such containers could increase the risk of certain vector-borne diseases, as a study conducted in Colombia pointed out a certain preference of *Aedes* for domestic vessels used for water storage

(Padmanabha et al. 2010).

Research and Measurement Challenges

While the risk of contaminated food and water sources has constituted a main point of interest in scientific literature, especially concerning diarrheal diseases, analyses are often facing significant bias in the data, due to indicators that are either too general or simply do not convey the reality on the field. Measuring access to water at the household level in particular is often a challenging enterprise: for example Heller (1999) draws attention to the fact that official statistics do not convey, in many cases, the actual situation of the population. For example, in the urban area of Betim (Brazil), actual coverage of piped water inside the household was in fact significantly higher than official statistics, due to clandestine connections which were not taken into consideration in public or concessionary figures. Thus, while the demographic census accounted for 19.9% of properties being unconnected to the network, epidemiological survey data showed that only 1.6% of compounds were in fact unconnected (Heller 1999). Another source of bias in the data mentioned in the study was related to the quality of water supply, as intermittent supply or improperly low water pressure can cause deterioration in the pipes, through biofilm formation. This, in turn, increases the risk of diarrheal diseases (Heller 1999).

Similar issues are mentioned by Dos Santos and LeGrand (2007) and Moy and colleagues (1991) with regard to the African context: using the main water source as indicator ignores significant variability between households and their strategies with regard to water supply, since in many African cities, the water source is multiple. Frequent water cuts mean that households with access to a current water supply may be forced to resort to other strategies for their needs in terms of water. Here, other confounding factors such as practices of boiling water and storage contamination intervene (Dagdeviren and Robertson, 2009, cited by Dos Santos, Ouédraogo, et al. 2015; Jalan and Ravallion 2003). Such practices are closely related to hygiene practices and knowledge, which in turn are influenced by education, be it formal or informal.

Aside from the water source, the time or distance spent to fetch water is an important determinant in developing countries, as it acts threefold. Firstly, it has been shown that longer times to fetch wa-

ter limit consumption, whereas using lower quantities of water can be associated with water-related diseases (Afullo et al. 2014; Dos Santos, Ouédraogo, et al. 2015). Secondly, in most cases in West Africa, it is women who are charged with fetching water (Sorenson et al. 2011; UNICEF and WHO 2008). This translates into less time dedicated to caring for children, who are potentially left in the care of secondary carers. In this context, Ray (2007) points to the fact that lack of or unsatisfactory access to an improved water source contributes to what the 2006 UN Human Development Report (2006) has called “time poverty” for women and children. Thirdly, as already mentioned, water that has been carried or stored for longer periods of time incurs increased risk of contamination during transport, which increases the risk of diarrheal diseases. For example, an analysis using data from DHS studies carried out in 26 countries found that the time spent walking to a household’s main water source was a significant predictor of both diarrheal prevalence and overall under-five child health (A. J. Pickering and Davis 2012). Similarly, concerning the distance to water source, results of a study conducted in Bangladesh (Prost, 1996, cited by Dos Santos and LeGrand 2007) show that over 200 meters to the water source would almost annihilate the beneficial sanitary effect of having water supply. One possible reason for this could be the increased risk of contamination posed by transporting water over longer distances.

Data from Zimbabwe showed a similar relationship between distance to the water source (measured with a 500 m threshold) and mean number of diarrhea attacks (Moy et al. 1991). However, results were not statistically significant, possibly due to the relatively small sample size, of 148 children. Bivariate results obtained in a study undertaken in Western Ethiopia (Girma et al. 2008) showed an inverse relationship: an increased distance to the drinking water source (the equivalent of more than 15 minutes’ walk) was associated with a lower under-five childhood diarrheal morbidity, but the significance was lost in the multivariate regression.

Despite this evidence, time to the water source may be difficult to accurately assess in surveys, since it is usually declarative and hence subjective, whereas the use of distances as proxy may be prone to underestimation, due to deficient road infrastructures. This is

especially the case in informal settings, where road infrastructures are often substandard (Dos Santos, Ouédraogo, et al. 2015).

Besides the source of water and time or distance needed to fetch it, the quantity and quality of water may also play a role in water-related diseases (Thompson et al. 2002 and Wright et al. 2004, cited by Dos Santos and LeGrand 2007). Despite this, there are not many studies which treat both (and separately) the impact of water quantity and water quality on diarrheal disease. This increases the difficulty in drawing conclusions as to the relative impact that each of the two has. However, in the past two decades, there has been increasing scientific interest in water quality improvements, specifically those regarding point-of-use treatment (Fewtrell and Colford 2004). While this type of interventions appears to be generally effective in reducing diarrhea, most studies in developing countries were carried out on small population samples and over short periods of time (Waddington et al. 2009).

Finally, an aspect to be taken into consideration when assessing the impact of measures to improve water supply and sanitation, is that they will only have a worthwhile effect between certain limits, below and above which, benefits will be limited (Fewtrell and Colford 2004). For instance, the issue of compliance is often brought up: having or receiving certain facilities and infrastructures is not always synonymous to using them. Adopting biomedically efficient behavior does not rely solely on the existence of the means to adopt them, but also on the perceptions and willingness of the population concerned; in other words, for usage, access to these infrastructures needs to be supported by knowledge and behavior (Dos Santos 2011). In one study mentioned by Fewtrell and Colford (2004), conducted in rural China, although taps were provided inside the compound, residents still stored water in the traditional manner (Fewtrell and Colford 2004).

This suggests that statistics, as quantitative evaluations, often ignore both the quality of the public services and the alternative solutions adopted by the population who benefits (or not) from these collective public sanitation services (Heller 1999).

Debate

Analyzing *Ae. aegypti* possible breeding sites in the city of Nha

Trang from Vietnam, Tsuzuki and colleagues (2009), found an impressive array of household items susceptible of harboring the vector. Specimens were found in small, medium and large-sized plastic buckets, concrete basins, jars, flower vases, wells, and discarded tires where water was added manually for experimental purposes. Among these, toilet concrete basins, wells, jars, large plastic buckets, concrete basins, and tires were found to be potentially the most important breeding containers, having shown high pupal productivity and efficiency during both of the two survey periods (Tsuzuki et al. 2009).

In a rural area of the Penang Island of Malaysia, after inspecting approximately 20 domestic containers (most of which did not contain water though), a study found 285 *Ae. albopictus* immature mosquitoes at various developmental stages in a container filled with water and kept inside a bird cage (Dieng et al. 2012). Similarly, Aziz and colleagues (2012) found specimens of adult *Ae. aegypti* in the arid area of Makkah City (Saudi Arabia), during a one-year observation period, from April 2008 to March 2009. Although mosquitoes were more prevalent during the wet season, their existence was recorded throughout the study. The authors explained this as a result of water storage practices used by locals, due to the scarcity of water resources (Aziz et al. 2012). Since generally water is stored for long periods of time in large-sized containers which are usually kept uncovered, in shaded areas of the compound, they would normally favor *Aedes* breeding, as *Aedes* mosquitoes have been found to prefer resting inside houses and laying their eggs in domestic containers (Dieng et al. 2012).

Nevertheless, directly linking water storage with malaria risk did not yield a significant association between storage of water in clay pots and increased malaria in children living in the city of Man from Ivory Coast (Matthys et al. 2006) and in peri-urban areas from the Gambia (Koram et al. 1995b). This may be due to the preference of the *Anopheles* mosquitoes (unlike *Aedes*) for breeding in clean, natural water bodies (Byrne 2007).

Therefore, data seems to suggest that further investigation concerning the characteristics of these water-storage containers and possible interactions need to be assessed, since they may have different effects on various febrile illnesses.

As already stated, literature suggests that improvements regarding the quality of water are only efficient in the context of already satisfactory sanitary conditions (Fewtrell and Colford 2004). Thus, the real crucial step in reducing diarrheal disease is sometimes regarded to be a constant water supply and increasing the quantity of water used for personal and domestic hygiene (Timaues and Lush 1995). Data with regard to the role of access to water is abundant, but results are sometimes inconclusive. For instance, a meta-analysis by Fewtrell and Colford (2004) on the effect of water supply on diarrheal disease, found a pooled estimate of 0.509 (95% CI: 0.471 – 0.551) in established market economies. In developing countries, the results remained consistent and the pooled estimate was even higher: 0.749 (95% CI: 0.618 – 0.907). However, the studies referred to both household connection and communal standpipe and the meta-analysis included an ecological study and another study where the outcome variable was only cholera, rather than diarrhea in general. When the two studies were removed from the meta-analysis though, the results were no longer statistically significant, neither concerning the household connection, nor concerning the communal standpipe. Also, the meta-analysis found water quality and point of use to not be statistically significant in established market economies, but to be significant in the case of developing countries. The authors explained the lack of statistical significance by the potential quality issues of several of the studies included in the meta-analysis: control group, the presence of confounders and indicator definitions. Also, the distinction between water quantity and water quality is often problematic, since water consumption levels are, in most cases, not documented (Fewtrell and Colford 2004). Another risk for biased results could be that, typically, water quality improvements usually concern either plant improvements or point of use interventions, thus leaving much space for water contamination along the way. Also, the authors warn that storage inside the household is still largely prevalent in developing countries, which may further contribute to possible contamination. The meta-analysis consisted of studies focusing on point of use (household) improvements, such as chemical treatment, boiling, pasteurization and solar disinfection. While most of the studies analyzed suggested that (point of use) water treatment and proper storage do indeed limit the risk of diarrhea, especially in rural areas, compliance at

household level is, in most cases, difficult to assess (Fewtrell and Colford 2004).

A study focusing on intestinal parasitic infections conducted in Riyadh (Saudi Arabia), found that using water from tankers (as opposed to connection to the general network) was associated with a slight increase in diarrhea, both for Saudi children of less than 12 years old (OR: 1.53; 95% CI: 1.04 – 2.25) and for the population aged 12 and over (Al Shammari et al. 2001).

Water source was also found to have an impact on diarrhea in a study conducted in four villages from Malawi, where results have shown a significant decrease in risk of diarrhea (OR: 0.16; 95% CI: 0.08 – 0.32) in children who used a private tap, rather than the public network (Masangwi et al. 2009). However, no impact was found between the latter and using a well or a borehole. This could be due to the aforementioned problems regarding public water supply, which render it sometimes of inadequate quality for drinking. In the same study, an aspect related to both water supply and hygiene practices – that of the water used for handwashing – showed statistically significantly lower odds associated with using tap water, as opposed to pouring water from a container (OR: 0.10; 95% CI: 0.02 – 0.05) (Masangwi et al. 2009). This could be due to possible contamination of water through improper storage and would thus confirm the importance of water quality, as well as quantity, in diarrhea reduction.

Several other studies found no relationship between access to water and risk of diarrhea. In a case-control study in Salvador (Brazil), access to piped water, the presence of a water filter and the lack of water interruptions did not diminish significantly the risk for diarrhea in children below 5 years of age, after accounting for the socio-economic status of the family (Seigel et al. 1996). The samples used in the study were, however, quite small, of less than 60 cases per socio-economic category. This could also be the reason why Moy and colleagues (1991) did not find a relationship between water source or quantity and diarrhea. Similarly, Heller (1999) found no significant increase in the risk of diarrhea for the population unconnected to piped water. The author offered two possible explanations for the lack of association, namely the small sample size used and a possible lower diarrheal risk for the population that was

unconnected (such as better hygiene practices, to compensate for the inadequate water supply). The role of a water storage tank was also analyzed here, and results suggested an inverse relationship to that observed in other studies: households lacking such a tank were found to be slightly more at risk than those which stored water in tanks (RR: 1.91; 95% CI: 1.01 – 3.6). Normally, having water stored in tanks is considered to be a diarrhea risk factor, but the author underlines that the risk posed by water tanks is strongly intertwined with household practices regarding inadequate maintenance (Heller 1999). Similarly, Timaeus and Lush (1995), citing two studies (Stephens, 1984 and Esrey and Habicht, 1988), underline that the effect of improved water and toilet facilities on child health may vary between individuals and populations, depending on parental education, suggesting an interaction between socio-economic status and sanitation. A similar observation is that the impact of water supply is often mediated by hygiene practices (Masangwi et al. 2009). Thus, even populations which benefit from “improved” water sources may drink water which is unfit for consumption, due to unhygienic handling within the compound.

Conversely, when mothers adopt health-promoting practices, these may limit the negative effect of improper water supply. Jalan and Ravallion (2003) found that for educated women, the impact of piped water on both the duration and prevalence of diarrhea in children below five years in rural India was significantly lower. The authors argued that it is likely because skills and knowledge such as proper storing of water and boiling would be required to make water drinkable, so educated mothers may be able to adopt these skills more easily, thus rendering the effect of water supply less relevant.

These results suggest that the impact of water supply is often mediated by other variables pertaining to the individual and to the family. For example, the role of water supply appears evident only after the first two years of life (probably due to the protective role of maternal milk, before that age, which limits the risk of disease) (Dos Santos and LeGrand 2007). However, the authors found that the protective role of the current water supply becomes statistically insignificant when variables referring to the socio-economic and cultural status of the mother (notably the education level) are

introduced in the model. These results were consistent in the case of very young children, of less than 5 years old.

In a similar line of thought, Seigel and colleagues (1996) found that only in the case of children belonging to higher socio-economic categories (but not in the case of children belonging to the lower one), the children with diarrhea (cases) had access to significantly fewer water sources than children without diarrhea (controls). This would imply that there is a possible interaction between socio-economic status and the extent or the way in which certain environmental factors – such as water supply – influence the risk for diarrheal disease. A similar interaction between the two variables resulted from Jalan and Ravallion's (2003) study from rural India. The authors found that the impact on child diarrhea became more important from the 40th socio-economic quintile onwards and for children of educated women. In other words, the beneficial effects of water supply were stronger for the categories of population with higher socio-economic status, which the authors posit acts like a proxy for ensuring health-promoting conduct (Jalan and Ravallion 2003). Similarly, the health gains of access to piped water were more important in families with better educated women (Jalan and Ravallion 2003). Also, the contribution of education itself varied with that of wealth: in the lowest two quintiles, the effect of education overrode that of wealth, since having an educated woman in the household meant that the latter extracted beneficial health outcomes from piped water. However, in the upper quintiles, the impact of female education was non-significant (Jalan and Ravallion 2003). The authors also found little difference in terms of prevalence of disease between households using their own piped water inside the compound, as opposed to those using the public tap (Jalan and Ravallion 2003). However, in families where the female member was uneducated, there was a significantly higher prevalence of diarrhea associated with the use of a public tap. Also, with regard to disease duration, the authors found an average of 40% longer duration, in the case of public tap usage. The explanation given is that the risk of contamination due to storage is much lower in the case of a private tap inside the household.

These aspects call into question the indicators most commonly used for analyzing the relationship between water supply and diarrheal

or vector-borne febrile risk and could partly explain the sometimes contradictory results obtained by different studies. It seems thus that, according to existing literature, current water supply is necessary, but not sufficient in combating child infectious diseases. It must be combined with improving food and personal hygiene practices, in order to be effective. Moreover, water supply and quality interventions may have little or no effect in the absence of hygiene compliance, such as ceasing to store water (in improper or uncovered containers) prior to consumption (Fewtrell and Colford 2004).

Another aspect that appears in several of the studies analyzed is that water supply improvements do not affect all categories of population alike, suggesting a possible interaction between socio-economic status (most notably the mother's education) and access to water. In other words, variables related to household wealth and maternal education may shape the way in which access to water influences health status.

Since one of the main goals of this thesis is to investigate potential risk factors in the household environment and since access to water is an important aspect of the domestic setting, indicators related to access to water will be used for creating a variable related to domestic environment, which, in turn, will constitute one of the covariates of the study.

Sanitation

Context and Mechanism of Action

Sanitation typically refers to the provision of facilities and services to safely dispose of human excreta (WHO 2019b). It refers to indicators pertaining to both household and neighborhood, which are thus interconnected. At the household level, improved sanitation refers to the following (Evans and Haller 2005):

- Connection to a public sewerage system
- Connection to septic system
- Pour-flush latrine
- Simple pit latrine
- Ventilated improved pit latrine

Across the globe, sanitation coverage and standards vary considerably, from almost complete coverage of sanitation facilities in Europe, North America and Oceania, to less than half in rural Africa and rural Asia (Fewtrell and Colford 2004). Worldwide, around 2 billion people worldwide do not have access to basic sanitation facilities, although improper sanitation facilities are considered to pose a major risk with regard to health, particularly in the case of diarrhea (WHO 2019b). Thus, potential economic benefits involved with sanitation investments suggest that as many as 391 million cases of diarrhea could be annually averted, if sanitation targets provided by the WHO/UNICEF Joint Monitoring Program were met (Evans and Haller 2005).

Research and Measurement Challenges

It has been asserted that if access to sanitation were universal, diarrhea episodes could be reduced by as much as 16.7% (Monteverde et al. 2010). If, added to that, water was disinfected at point of use, the reduction of episodes would be of 53% (Monteverde et al. 2010).

However, achieving these goals can sometimes prove to be problematic, since benefits are closely related with knowledge and usage by the population. As in the case of water supply, there is a relationship between sanitation and variables pertaining to socio-economic status. Monteverde and colleagues' (2010) study on 809 dwellings from the Buenos Aires conurbation showed that the lack of coverage was higher in more vulnerable dwellings from the point of view of the education: 31% of the population living in households whose head had a low level of education (unfinished primary or less) did not have sanitation and current water supply, as opposed to 24% of the population living in households whose head had at least finished primary education (Monteverde et al. 2010).

Moreover, the fact that a household disposes of excreta in the open, rather than using sanitation facilities, poses a risk also for the population living near the area, regardless of whether or not they have access to sanitation. Results are often inconclusive, given the wide range of alternatives to sewerage-connected toilets. These alternatives are often unstated, which makes comparison even more difficult to establish. Lower-income households may use various types of pit latrines or pour-flush toilets discharging to septic tanks or

to open drains, which pose various degrees of risk with regard to diarrhea (Norman et al. 2010).

Also, there are relatively few studies that have discerned the role of sanitation, compared to and controlling for other factors pertaining to the environment. Hence, there is currently little information available on the effectiveness of sanitation interventions in limiting diarrheal disease (Fewtrell and Colford 2004).

Debate

Studies considered here generally show a certain reduction in diarrhea indicators with improved sanitation: a pooled estimate of two studies from developing countries showed an estimate of 32% reduction in relative risk of diarrhea (RR: 0.678; 95% CI: 0.529 – 0.868) (Fewtrell and Colford 2004). Another meta-analysis found a pooled RR estimate for the effect of sewerage to diarrhea of 0.70 (95% CI 0.58 — 0.84), indicating a reduction of about 30% in diarrhea incidence and in other indicators of enteric disease burden (Norman et al. 2010). Data suggested that the impact of sewerage is most important when the baseline scenario is a very poor one. In other words, it is likely that the population who gains the most from sanitation interventions is the one whose initial situation was most unfavorable.

A study conducted on 16608 children aged up to 4 years old from an area near Dhaka (Bangladesh) found the use of sanitary latrines (with fence and platform) to be protective against diarrhea, compared to the use of other types of latrines, which yielded an OR of 1.59 (95% C.I: 1.34 – 1.88) (Myaux et al. 1997).

Having a flush toilet in the compound (as opposed to no facility at all) was associated with a significantly lower diarrhea incidence (3.02 episodes/child/year, compared to 6.19 episodes/child/year) in a multivariate analysis on 1275 children aged less than 5 years, studied from November 1989 to November 1990 in the Brazilian city of Salvador (Moraes et al. 2003). The results suggest a significantly increased risk of diarrhea for groups with less sanitary infrastructure. The study did not account for family-interdependences between children, but given the strength of the association and the size of the sample, it is likely that results would remain significant.

Conversely, Fahrmeir and Khatab's (2008) geoaddivitive modelling of

general child morbidity in Nigeria using DHS data found that neither having flush toilets nor having electricity provided significant protection against morbidity, but rather improved the nutritional status of children.

Owning a toilet was found to be protective with regard to diarrhea, as opposed to not using any toilet, in a study conducted on 1014 households from four villages in Malawi (Masangwi et al. 2009). Thus, not using a toilet was associated with an odds ratio of 1.72 (95% C.I.: 1.18 – 2.51), compared to owning a toilet. Using a public toilet also seemed to slightly increase the probability of diarrhea (OR = 1.14), but the results were not statistically significant.

Interestingly, Al Shammari and colleagues (2001) did not find a connection between sewage disposal (in the open or using a network) for Saudi children from Riyadh, but did for individuals aged 12 years or more, for whom disposal in the open was associated with an OR of diarrhea 2.26 times higher (95% C.I.: 1.27 – 4.05). Results were similar for the study population as a whole (OR: 2.43, 95% C.I.: 1.54 – 3.84).

Both latrine availability and latrine ownership (be it a private or a shared one) were significant protective factors in the study by Girma and colleagues (2008) in Ethiopia in bivariate regressions, but lost significance in the multivariate model. The presence of feces around the pithole/slab/floor of latrine did, however, remain a statistically significant risk factor, even in the multivariate model. Similarly, Heller's (1999) study on the urban area of Betim in Brazil analyzed both the impact of waste water and of excreta disposal strategies at the household level (using sewerage system as baseline scenario). While the variable was found to be statistically significant in bivariate analysis, after applying multivariate analysis, it also lost its significance.

The issue of the lack of statistical significance was reported by many other studies. Using data from the 2005-2006 DHS from India, Yadav (2017) found that while an improved toilet facility did not lead to a significant reduction in the risk of diarrheal and febrile infections for children under five in India, having improved water supply in the household offered protection against infection. However, the author did not take into account potential confounders, such as

wealth and sanitary equipments at the neighborhood level. Similarly, no significant relationship was found between diarrhea and the type of excreta disposal (ground or open drains, as opposed to sewerage system), in a study on 184 children aged less than two years from Canabrava (Brazil) (Heller 1999). Neither was the relationship with the absence of a toilet significant, where the prevalence ratio of a toilet was 1.67 (95% C.I.: 0.94—2.97) (Rego et al. 2005). Similarly, Seigel and colleagues (1996), in a case-control study on children of high and low socio-economic status in Salvador (Brazil) found no connection between having an indoor toilet and diarrhea, within each socio-economic group. Neither did Moy and colleagues (1991) find conclusive evidence, in their prospective study on 184 children from rural Zimbabwe, on whether having no toilet or latrine, as opposed to a toilet, constituted a risk for diarrhea.

These cases of lack of statistical significance could be, in part, linked to toilet using practices. Thus, if families are not educated to properly use toilets, the efficiency of the latter is at most marginal. Moreover, unless most of the households in the area use improved sanitation facilities, the risk of contamination remains high (Moy et al. 1991), probably due to the presence of pathogens in the vicinity of the compound.

The Eritrea-centered study by Woldemicael (2001) found an inverse relationship: having toilet facilities increased the odds of diarrhea by 40% (significant at 90% CI), which the authors attributed to a greater confounding with the place of residence (rural/urban). However, the models included in the study showed an increase in odds for diarrhea in children both in a model which included and in a model which did not include the place of residence.

In Monteverde and colleagues' (2010) study on 809 dwellings from the Buenos Aires conurbation, lack of sanitation showed a marked increase in the probability of disease. When analyzing possible interactions, lack of sanitation facilities was found to have a greater influence in the less educated category of population, suggesting an interaction between sanitation and socio-economic vulnerability of the household (Monteverde et al. 2010). Thus, the negative effects of the lack of sanitation tend to be accentuated by lack of education.

In Timaeus and Lush's (1995) comparative study on four countries, results differed according to location. In Ghana, it was toilet facilities that were the strongest related to diarrhea. Thus, having no toilet facilities yielded an odds ratio more than twice that of households with a WC, but no significance was reached in the case of pit latrines and improved pits. In the same study, authors found that a shared toilet increased the likelihood of having diarrhea by 60% in Egypt. In their analysis for Brazil however, the authors noticed an interaction with socio-economic status. There, poor toilet facilities were associated with higher diarrhea rates only in the case of children living in poorer areas. Thus, the authors attract attention that there is another variable which may interfere in the relation between sanitation facilities and risk of diarrhea: households' adoption of sanitation services. The authors postulate that, while the environment may influence diarrhea exposure directly, family practices to prevent diarrhea may intervene in the case of better off families. However, the authors caution that data did not permit international comparisons.

The role of toilet type in vector-borne diseases is less studied *per se*, the variable being more often included in an index of general household wealth and economic status (Pullan et al. 2010; Yusuf et al. 2010). However, the type of toilet itself could have an impact on mosquito presence: Tsuzuki and colleagues (2009) found that the number of larvae / pupae depended largely on the type of water recipient available, toilet concrete basins displaying among the highest levels of efficiency for *Ae. aegypti* breeding.

Similarly, in an urban area from the Penang Island in Malaysia, Dieng and colleagues (2012) found *Aedes* eggs inside the flush tank of a toilet in one of four houses visited. Thus, it seems that it is not only the toilet basin which can constitute a breeding spot for *Aedes* mosquitoes, but also the flush tank. It could be therefore argued that the type of toilet and its placement (inside or outside of the compound) could influence the efficiency of the vector, thus creating lesser or greater risks of infection for the household members. This being said, data with regard to the role of sanitation in mosquito-borne diseases remains rather sparse.

However, just providing the necessary infrastructure – be it at the household or at the neighborhood level – is often not enough, in

order to insure proper usage by the population. Interventions in India showed that 40% of households with access to a latrine had at least one resident who still chose to defecate in the open (Burki 2015). The reasons mentioned were convenience and comfort, in the context where local population generally did not link hygienic practices with childhood illnesses. The authors also cite the case of Ethiopia, where the prevalence of open defecation was brought down from 94% in 1990 to 37% in 2012, but by introducing additional measures. Among the measures identified as contributing to this change were assigning a large number of health workers to promote sanitary and hygiene practices within the community, together with breastfeeding infants and routine immunisation.

Although somewhat conflicting, data seems to suggest that owning improved sanitation facilities lowers the risk of water-related diseases, despite a somewhat lower interest in the role of sanitation, compared to that of water quantity and quality. Therefore, as with access to water, an indicator of sanitation at the household level will be used for creating a synthetic variable related to domestic environment.

Waste Storage and Disposal

Context and Mechanism of Action

Although improper storage of household waste can favor transmission of pathogens, the conditions in which refuse is stored inside the compound are rarely tackled (Heller 1999).

The relationship between insufficient garbage collection or improper storage and diarrheal diseases is fairly straightforward, as garbage may often be contaminated with faeces (Limpurb, 1999, cited by Rego et al. 2005). Similarly, not benefiting from regular garbage collection could increase the risk of both malaria and dengue, since keeping garbage around the compound for longer periods of time can attract vectors. Particularly in the case of dengue, its vectors are able to exploit numerous artificial domestic water-filled containers (Hayden et al. 2010; Sutherst 2004).

Research and Measurement Challenges

The role of garbage storage and disposal at household level is in a close relationship with that at neighborhood level. It is difficult to assess and decant the impact of a household's strategies, because

disposal strategies adopted by a part of the population (such as dumping on an empty plot of land) can impact on another part of the population. This is because improper disposal of waste by other families can impact on garbage presence in the area, with the population living near the dumping ground being the most affected (Heller 1999). For example, street disposal, where collection is less than twice a week, or disposal in streams or on empty lots, most affects the population living near the areas in question (Heller 1999).

Debate

The garbage disposal method was found to play a significant role in general risk of mortality for children aged up to five in the capital of Burkina Faso, Ouagadougou (Dos Santos and LeGrand 2007). Thus, children living in compounds where household waste was disposed of in a public dump incurred almost twice the risk of children living in compounds where waste was collected by a service (RR: 1.78; p-value: 0.05).

This being said, study results tend to differ, both with regard to risk for diarrheas and for vector-borne diseases. While storing refuse in improper bags increased the risk of diarrhea (RR: 1.97; 95% CI: 1.55 – 2.5) in children below the age of five, in a multivariate analysis on around 1000 cases and 1000 controls from Betim (Brazil) (Heller 1999), it did not yield significant results in a cross-sectional study also conducted in Brazil, on 184 children from Salvador (Rego et al. 2005). Whether waste was unpackaged (swept to the street or backyard) or kept inside a form of packaging (plastic bag, dustbin) did not show a statistically significant relationship with diarrhea, although lack of packaging yielded a higher prevalence ratio, of 1.57 (95% C.I.: 0.90—2.73). However, garbage collection was a significant variable in relation to diarrhea, in the aforementioned study (Rego et al. 2005). The study focused on means of disposing of household waste, using responses coded as: ‘street’ (which included garbage thrown into the yard), ‘stream’ (an open trench designed to carry away sewage and/or drainage), ‘vacant lots’, and ‘collected garbage’. The responses were then grouped into ‘not exposed’ (the case of those using collected garbage) and ‘exposed’ (all other responses). Results showed a significant increase in risk of diarrhea for children living in compounds where garbage was inappropriately

disposed of (Rego et al. 2005).

Lastly, with regard to mosquito-borne febrile illnesses, no significant relation was found between garbage disposal and dengue in the city of Belo Horizonte in Brazil (de Mattos Almeida et al. 2007), but the authors used aggregated data in their study, basing their results on the proportion of households connected to a garbage disposal service. Concerning malaria, although less studied, temporary *Anopheles* breeding sites can appear – such as in the case of Dakar – in garbage cans or debris (Machault et al. 2009).

Similarly to access to water and to sanitation, waste storage and disposal represents one of the main indicators of domestic environment and will therefore be used as indicator for creating a variable related to domestic environment.

Crowding

Context and Mechanism of Action

While generally, an increased number of members per room tends to be considered as a risk factor for diarrheas (due to higher possible transmission from one member to another ⁸), its impact on mosquito-borne diseases is subject to two opposite hypotheses. The first one considers that a larger density per household could be a protective factor, since a higher potential of hosts would reduce the risk of one particular host being infected. This, in turn, would translate as lower inoculation rates in households where more people share the same (sleeping) room (V. Robert et al. 2003). On the contrary, other authors argue that greater human meal potential leads to an increase in the number of mosquitoes that the area can support and this – in turn – generates a higher risk of disease transmission. Consequently, sleeping in separate rooms and thus making it more difficult for mosquitoes to identify blood meals could constitute a protective factor (S. W. Lindsay, Emerson, et al. 2002).

Research and Measurement Challenges

A particular difficulty regarding mosquito-borne infections is that

⁸This is especially true in slums, where crowding is caused primarily by poverty; since poorer families are also more at risk of being malnourished, they are more at risk to develop a severe form of disease if exposed to the pathogen (Osborn 1998)

results may also depend on the mosquito species and its breeding/resting habits. Konradsen and colleagues (2003) analyzed the presence of two species of malaria transmitting mosquitoes in rooms and found that the ones in which more than two people had slept had a higher presence of *An. culicifacies*, but the factor was not significant concerning *An. subpictus*. These results do not necessarily reflect malaria transmission associations though, but vector density is a key variable in the equation for a vector's capacity to transmit infections (Tolle 2009).

Moreover, defining overcrowding can be rather problematic, as it is – between certain limits – strongly associated with perceptions and cultural norms. The perception of overcrowding is, to a great extent, a function of “standard dwelling unit sizes, family groupings and other cultural norms. In some cultures, and among some ethnic groups, living in close quarters is preferable to living in smaller family groupings” (United Nations Human Settlements Programme 2006, p.71). As a result, the same conditions may be desirable in some cultures, but considered as crowded in others.

In this context, measuring overcrowding is typically done by one of two indicators: living surface area per household member or number of household members per dwelling, per room or per bedroom (United Nations Human Settlements Programme 2006). Since the first indicator, of living surface area per household can be sometimes difficult to measure (due to differences in the definition of “living area”), most often the second indicator is used, that of the number of persons per room or bedroom. UN-HABITAT defines having enough space as “A house is considered to provide a sufficient living area for the household members if three or less people share the same room” (United Nations Human Settlements Programme 2004).

Debate

In terms of risk for diarrhea, Woldemicael (2001), using DHS data for Eritrea, found that the number of children living in the compound constituted a risk to diarrhea in children of less than three years old. Thus, having 3 to 5 children was associated with an OR of diarrhea 1.3 times higher than in the case of less than 3 children, while having over 6 children posed was 1.64 higher (Woldemicael 2001).

Similarly, a study on four villages from Malawi found that households with five or six members were slightly more likely to experience diarrhea in children than those with only two members, the results being significant at a 90% confidence interval (OR: 1.83; 90% CI: 1.01 – 3.32) (Masangwi et al. 2009). The likelihood of diarrheal prevalence seemed to increase with the number of household members, but results were not statistically significant, as was the case of households with 3 to 4 members.

Other studies have also reported inconclusive results: for example, a cross-sectional study conducted in the Brazilian community of Canabrava, a neighborhood close to Salvador’s garbage dump, found no statistical relevance for diarrheal prevalence ratio associated with having more than two people per room (95% CI: 0.83 – 2.59). In another study in Salvador, Seigel and colleagues (1996) found no association between overcrowding and the occurrence of diarrhea in children. The study was a case-control study, but with a relatively small sample size, with only around 50 cases and their matched controls for each of the two socio-economic categories the authors studied.

Similarly, regarding the co-occurrence of a diarrheal and febrile episode in children under five from Malawi, a Bayesian analysis of the 2000 DHS Malawi dataset found no significant impact of crowding on the relative odds ratio of co-morbidity (Kazembe and Namangale 2007).

Concerning vector-borne diseases, Yamamoto and colleagues (2010) found no significant relation between the number of rooms in the house and clinical malaria in children from a semi-urban area in Burkina Faso. Contrarily, Ghebreyesus and colleagues (2000), analyzing household risk factors for malaria incidence among 2114 Ethiopian children less than 10 years old, found a significant increase (1.52; 95% CI: 1.05 – 2.20) in risk of malaria parasitemia for children belonging to households with only one sleeping room, which would support the hypothesis of human density acting as an attraction to mosquitoes. Neither of the two studies however, measured room density or crowding (i.e. the number of persons per room), which renders households uncomparable.

On the other hand, Koram and colleagues (1995b), using a thresh-

old of three persons per room, observed that twice as many children with malaria were sleeping in crowded rooms, compared to their controls. The difference was significant in a multivariate model, with an adjusted odds ratio of 1.8 for sleeping in rooms with more than three people.

With regard to dengue transmission, the results of Braga and colleagues (2010) suggest that a greater density of inhabitants per room increases the risk of infection. Studying three areas in the city of Recife (Brazil), the authors set a threshold of more than one person per room, and found that seroprevalence was higher with room density.

Since results in existing literature with regard to crowding appears to be rather inconclusive and since crowding does not represent one of the aspects of interest in this research, a variable measuring crowding, using a threshold of three persons per room, will be used to test a potential impact on water-related diseases. If this variable does not appear to play a role on the diseases in question in bivariate analyses, it will not be included in the final, multivariate, statistical models.

Dwelling Type

Context and Mechanism of Action

Some housing characteristics can influence the risk of malaria by facilitating (or impeding) the vector-human contact (V. Robert et al. 2003). In general, poorly constructed houses can constitute a risk factor for malaria and dengue infections in several ways. Openings, unscreened windows and eaves can facilitate the access of mosquitoes into the compound, while cracks and crevices in walls can constitute hiding places (Konradsen et al. 2003; S. W. Lindsay, Emerson, et al. 2002; V. Robert et al. 2003; Yamamoto et al. 2010).

With regard to diarrheal disease, the impact of dwelling characteristics has been less documented and there is hardly any evidence with regard to the possible ways in which they can influence diarrheas. However, interactions between floor and wall type and the impact of sanitation on reducing diarrhea have been documented in the city of Salvador from Brazil (Moraes et al. 2003). This may be especially important in the case of younger children, who tend

to crawl and spend a significant amount of time close to the ground (Ngure et al. 2013).

Research and Measurement Challenges

Most aspects of house design are often in close relation with the socio-economic status of the family (Konradsen et al. 2003; S. W. Lindsay, Emerson, et al. 2002; Nahum et al. 2010). In other words, a low socio-economic status is generally associated with poor housing conditions: for example, a study in the town of Man (Côte d’Ivoire), found that 73.1% of the poorest and 63.2% of the very poor households inhabited houses with wooden walls sealed up with traditional clay (Matthys et al. 2006). Therefore, in order to decant the role of each of the two dimensions, controlling for wealth or revenue of the household and for educational level is necessary. Also, the general “house condition” can be difficult to assess, making results obtained by different studies sometimes incomparable.

Debate

Certain studies reported that the type of construction can also have an influence on parasitemia, with lower quality materials being associated with increased risks, particularly for mosquito-borne infections. A study in seven villages from Southeastern Sri Lanka (Gamage-Mendis et al., 1991, cited by Konradsen et al. 2003) between 1996 and 1998 found that uncompleted houses, mud or local material walls, as well as thatched roofs contributed to a higher incidence of malaria. A possible explanation for this may be that an incomplete, unfinished construction or one made from non-durable materials constitutes a higher risk for openings and cracks through which mosquitoes can enter the compound. Mud walls on houses were found to constitute a risk factor for malaria in a peri-urban region from the Gambia (Koram et al. 1995b). The risk associated with mud walls was 1.73 (95% CI: 1.09 – 2.81 at) times higher than that associated with cement or brick ones. However, when comparing severity of the disease in another study (Koram et al. 1995a), the authors found no statistical significance between the house construction of children with severe malaria and those with mild infections. In the same study, the material used for walls did not constitute a significant risk factor for severe malaria, as opposed to mild malaria, when controlling for mosquito protection measures and socio-economic variables (Koram et al. 1995a).

In a study on dengue fever in Douala, Cameroon, based on a standardized interview and blood samples taken in 2006–2007, found an association between the type of construction materials and dengue seropositivity. Thus, living in a house with walls made of temporary materials, as well as natural ventilation (compared to air conditioning), were found to increase the odds of having dengue antibodies in the blood (Demanou et al. 2014).

In the north of Peru, adobe and wood/mud walls were associated with an almost twofold (1.86; 95% CI: 1.16 – 2.87, respectively 1.80; ; 95% CI: 1.17 – 2.76) increase in risk of malaria incidence (defined as *Plasmodium* infection and clinical malaria symptoms), but the association was not significant in a multivariate analysis (Guthmann et al. 2001). The presence of open eaves though was a significant risk factor (1.88; ; 95% CI: 1.25 – 2.81) in multivariate analysis, suggesting that larger openings favor the access of mosquitoes inside the house, where they afterwards have easier access to human blood meals (Guthmann et al. 2001).

In a study in Ethiopia, the presence of openings or holes in walls, windows or the type of roof had no impact on febrile illness related to malaria (Deressa et al. 2007). However, their study does not account for malaria *per se*, but febrile illnesses which are – in certain circumstances – associated with clinical malaria symptoms.

Contrarily, in a study conducted in 1997 in a hypoendemic area of Ethiopia (Ghebreyesus et al. 2000), the presence of open eaves, a roof made of earth and the presence of windows were all found to increase the risk of positive parasitemia in children. However, the type of windows was not specified in the study and therefore, the risk associated with the presence of windows could be significantly lower, if the latter are equipped with screens.

Snow and colleagues (1998), found no significant association between the type of construction and the risk of malaria in children admitted to the Kilifi district hospital on the Kenyan coast. While not analyzing the data by means of a hierarchical model, the authors did take into account socio-demographic variables, by considering them as confounders for the environmental variables of interest. In their study, neither the presence of open eaves nor that of ceilings (which are probably closely related to the socio-economic

status of the household) caused a significant variation from severe malaria to mild cases or to community controls.

These findings suggest that – while most probably protective against infective bites – the quality of the house construction mosquito house proofing may be of less importance in differentiating between a mild case and a severe one. This could be related to the concept of delayed acquired immunity (Clarke et al. 2002; V. Robert et al. 2003), which refers to the fact that individuals living in lower-transmission environments acquire immunity to *Plasmodium* parasites later than those living in hyper- or holo-endemic ones. Thus, once infected, the risk of developing acute symptoms is higher in the former than in the latter.

Therefore, it is likely that the impact of house construction changes would be more successful in cities and other areas of low transmission, where a reduction in (indoor) mosquito biting can have an important impact on disease incidence (S. W. Lindsay, Emerson, et al. 2002). The role of house age in malaria infections was also studied. In the Grau region of Peru, houses built four or more years before the fieldwork, were associated with a significantly increased risk of clinical malaria (Guthmann et al. 2001). The authors explain this finding through the fact that older houses are probably deteriorated and allow the access of *Anopheles* inside the compound. However, they also specify that, during fieldwork, the general impression was that the difference was rather between proper and badly constructed houses, than between old and new houses.

Contrarily, results of a study conducted in a semi-urban area from Burkina Faso showed a particularly high risk precisely in newer houses, those built less than ten years before the fieldwork, compared to those 40 years or older (Yamamoto et al. 2010). Roof, wall and floor material had no significant impact, whereas house tenure (owned vs. borrowed/rented), while significant in bivariate analysis, lost statistical significance once other variables were added to the model. One possible explanation for this is that in the study, house ownership was significantly positively associated with house age, in that newer houses were generally built for renting. Since rented houses would most probably benefit from less investment both from the part of the owner and of the tenant, this would mean that the quality of the compound in such situations would

probably be lower.

Moreover, significant degradation is probably less likely to occur within short durations of time, such as a few years; in this context, it would seem more likely that the construction quality (rather than its age) determines malaria (and possibly dengue) transmission risks. Koram and colleagues (1995b) also found that, in a peri-urban area from the Gambia, new construction of houses was taking place at a very rapid rate and the compounds and nearby areas were often lacking proper facilities and infrastructure, thus favoring mosquito breeding.

Concerning diarrheal disease however, data on whether the materials used for constructing the compound may constitute a risk factor is less developed, with rather sparse studies on the topic. For example, one study found that non-dirt flooring materials were a deterrent to diarrhea in young children in Eritrea (OR: 0.57), with a significance level of 0.1% (Woldemicael, 2011). Also with regard to the floor material (earth versus other materials) in the area of Canabrava near the city of Salvador (Brazil), while a study on diarrheal disease found an association between the two variables, it did not reach statistical significance. The sample size was, in this case, of 184 children aged less than 2 years, of which 33 lived in households with earthen floors (Rego et al. 2005).

Regarding wall materials, using the 2013 Nigeria DHS, Yaya and colleagues (2018) found that both having concrete walls and having concrete roof influenced diarrheal outcomes for children aged less than five. However, no statistically significant relationship was found between compounds made with brick, as opposed to mud/thatch walls, in a prospective study in rural Zimbabwe. This being said, the sample was quite small, of only 132 infants (Moy et al. 1991).

In this context, indicators pertaining to the dwelling construction will be added to the variable regarding housing amenities and their potential role on water-related diseases will be measured in this study.

Livestock

Context and Mechanism of Action

Keeping animals inside the family compound has been found to increase child deaths in general (H. Pickering et al. 1986). This may be related to poor general hygiene associated with keeping livestock inside the dwelling and with the presence of feces in the compound. However, there are relatively few studies which address the issue. Also, similarly to the case of crowding, the presence of animals in or around the compound is generally considered to be a risk factor in the case of diarrhea, but subject to debate in the case of vector-borne diseases. While animals can act as a “diversion” factor for mosquitoes which would otherwise feed on humans, in the case of certain *Anopheles* species which preferentially feed on humans (Sullivan 2010), the presence of animals may increase the mosquito density in the household (Ghebreyesus et al. 2000; Hasyim et al. 2018).

And, once inside, certain mosquito species will choose the human blood meal, thus increasing the risk of malaria transmission. Similarly, with regard to the feeding patterns of *Ae. albopictus*, it seems that that with equal availability of humans and calves, chickens, dogs and goats, mosquitoes showed a significant preference for feeding on humans (Dieng et al. 2012).

Research and Measurement Challenges

Most studies analyzed here support the hypothesis that mosquitoes, while potentially attracted by livestock, will eventually choose the human blood meal, thus making the presence of animals inside the compound a risk factor (S. W. Lindsay, Emerson, et al. 2002). However, comparability between studies again poses certain problems, since the definition of “keeping livestock in the household” can vary as to the number of animals kept and to the proximity to the living and sleeping area.

Debate

Koram and colleagues, (1995a) did not find any significance in the relation between the presence of animals in the compound and the risk of malaria, nor between severe cases, versus mild ones. However, the authors did not specify the threshold in terms of what number of livestock was set as threshold in the study, nor what they defined as “animals in the compound”.

Contrarily, Peterson and colleagues (2009) created a dichotomous variable for livestock presence within 10 meters of the house, with seven animals being set as threshold. The results of the study conducted in a highland area of Ethiopia showed a risk increase of malaria in adults, but no significant association concerning children (Peterson et al. 2009). A significant association (a positive one) resulted however from a Poisson regression model elaborated on data concerning children from a region in northern Ethiopia, where having animals sleep in the house conducted to an almost doubling of the risk of malaria (Ghebreyesus et al. 2000).

With regard to diarrheal risks, study results tend to be scarce. In one study conducted in Guinea-Bissau, children in households which kept pigs were 2.5 times more likely to suffer from diarrhea, whereas the probability associated with keeping dogs was 2.1 times that of children from households which kept no animals (Molbak et al., 1994, cited by Rego et al. 2005).

Both theory and research on the presence of animals in the compound and their impact on water-related infections in children seem therefore to offer little basis for clear conclusions on whether animal presence constitutes or not a risk factor for disease transmission. Hence, and given that livestock does not represent one of the key aspects in this study – as with crowding – I will test a potential relationship with water-related diseases and, in the event of a significant association, the variable will be included in the final statistical models.

Neighborhood Environment

Limiting the analysis to only taking into account the domestic environment is one of the factors which may explain, in part, why study results are sometimes contradictory – both with regard to diarrheal and to febrile risk factors. This is because often, the risk incurred by a household that does not have adequate facilities also extends to neighboring households, which find themselves at greater risk of contact with wastewater or garbage (Heller 1999). It is therefore necessary to also take into account the environment of the neighborhood in which the household is located.

The impact of factors belonging to the neighborhood level – al-

though less visible than in the case of household characteristics – could nevertheless be significant, since traits of the neighborhood can create a context that is favorable to the transmission of pathogens from one person to another. Moreover, the existence of household-level facilities (in terms of access to water and sanitation) may be partially counteracted by a lack of these facilities at the neighborhood level, which puts all the households in the area at higher risk (Heller 1999).

In terms of neighborhood, the main potential risk factors regard the lack of sanitation or the presence of wetlands. These two aspects favor the multiplication of vectors, serving as breeding sites. Subsequently, adult female mosquitoes tend to seek blood meals near breeding sites, making some areas more at risk for mosquito-borne infections than others (Pages et al. 2008; Pullan et al. 2010; Sriprom et al. 2010; Sullivan 2010). On the other side, still water and the presence of waste or faeces also increase the risk of proliferation of flies. This, in turn, facilitates the transmission of pathogens that cause diarrhea in people living close to the affected areas (Rego et al. 2005).

However, it seems probable that some environmental aspects do not influence all layers of population in the same way. Certain particularities, especially related to socio-economic status or to protective behaviors can alter the impact of the environment on health (Seigel et al. 1996). Thus, the environmental risks incurred by certain categories of population will be greater than those incurred by other categories, depending on characteristics such as level of education, income or knowledge of transmission and prevention of disease. In this context, it appears necessary to consider several levels of analysis, in order to account for the complexity and diversity of possible determinants of these diseases: individual child characteristics, socio-economic status of the family, the domestic environment and risk factors at the neighborhood level.

Solid Waste Collection

Context and Mechanism of Action

Deficient waste collection systems tend to be a non-negligible problem in large cities and one that is widely believed to have an impact on the risk of diarrheal diseases in particular (Muñoz-Cadena et al.

2009). There are two mechanisms for this. The first one is that proximity to garbage can increase the risk of diarrheal disease: large accumulations of organic waste favors the proliferation of vectors such as flies. This increase could, in turn, facilitate the transmission of disease within the population living close to the garbage dumps (Rego et al. 2005). The second one refers to the soil itself, which is known to often become contaminated with the solid wastes in question. And therefore, improper waste disposal practices favor the entry of enteric pathogens in high concentrations into the soil. The wind then may transport these enteric pathogens into water or air (Santamaria and Toranzos 2003).

Regarding mosquito-borne diseases, the *Ae. aegypti* mosquitoes, which prefer urban areas, often oviposit in places lacking infrastructure and adequate solid waste disposal (Hayden et al. 2010). This would make improper solid waste management also a potential risk factor for *Aedes*-borne diseases, such as dengue and chikungunya.

Research and Measurement Challenges

Despite a general agreement that lack of salubrity and solid waste constitute a risk for public health, few studies have analyzed the relationship between urban solid waste and health outcomes (Rego et al. 2005; Santamaria and Toranzos 2003). Scientific literature tends to focus more on aspects related to water supply and, in more recent years, to water quality (Fewtrell and Colford 2004). A possible explanation for this relative lack of information on the topic is that often, the presence of refuse improperly disposed of is ignored in statistics, although it affects the population living near the refuse dump (Heller 1999).

Debate

The few articles addressing this problem all found a positive relationship between presence of garbage near the compound and risk of diarrhea in children. Proximity to garbage was found to be a significant risk factor for population belonging to 809 households from the conurbation of Buenos Aires, in Argentina (Monteverde et al. 2010). Similarly to other environmental risk factors, living near a garbage dump posed more of a risk in the case of families whose head of the household had low education (coefficient associated to probability of diarrhea: 1.292, compared to 0.722 in the

case of families with an educated head of the household).

Heller (1999) studied diarrhea risk factors in Betim (Brazil) and found that street disposal, where collection occurs less than twice a week, or disposal in streams or on empty lots, affects the population living near these areas, where children under five had a relative risk for diarrhea 1.61 times higher (95% C.I.: 1.11 – 2.34). Unfortunately, there is not much information regarding the minimal frequency of garbage collection, so as to not pose disease risk and regarding intra-urban differentials.

With regard to mosquito-borne diseases, until recently, poor salubrity was considered to be a characteristic associated only with dengue fever, but not with malaria. It was thought that, while other species of mosquito breed well in dirty water, the appropriate breeding sites of *Anopheles* are in clean water (Mendez et al. 2000). *Ae. aegypti* on the other hand, breeds in stagnant waters forming in items such as old tyres, tins, plastic cartons, or bowls of water (Sriprom et al. 2010). Therefore, *Ae. aegypti* adapts better to urban environments, where “junkyards, car garages, flower markets, building material warehouses, and tire repair shops were classified as highly vulnerable to *Aedes aegypti* breeding” (de Mattos Almeida et al. 2007, p. 336).

However, more recent studies have discovered that *An. gambiae* manifests adaptability to urban habitats, breeding in water-filled containers and also polluted (Awolola et al. 2007; Pages et al. 2008). This would imply that disorganized garbage disposal and the presence of waste in the area in general could represent risk factors for malaria as well. Along that line of thought, some authors investigated the role played by markets (serving as proxy variable for lack of salubrity in the neighborhood) in water-related infections. The association yielded surprising results though, in relation to dengue fever. Using a variable that encompassed the distribution of commercial establishments considered “at risk” of constituting *Ae. aegypti* habitats, de Mattos Almeida and colleagues (2007), found a significant but negative association. However, the authors stated that their results might not reflect the actual nature of the association, since although they selected only certain commercial establishments (such as junkyards, car garages, flower markets, building material warehouses, and tire repair shops), they were not able to

measure qualitative aspects, such as the manner in which utensils and waste are discarded, since the study was based on secondary data (de Mattos Almeida et al. 2007).

Going back to the issue of garbage disposal, since its management at the household level is likely to be strongly related to the availability of infrastructures at the neighborhood level and since neighborhood environment in itself is a key factor in the current research, waste management at the neighborhood level will constitute one of the components of a synthetic variable on neighborhood sanitary infrastructures. This synthetic variable will, in turn, constitute an explanatory factor in the final statistical models.

Sewerage

Context and Mechanism of Action

While historically, the role of sewerage has been widely acknowledged as having had a major impact on public health during the ‘sanitary revolution’ of the 19th and 20th centuries, there is less evidence concerning its effect in present days (Fewtrell and Colford 2004; Norman et al. 2010). It is hence difficult to assess whether the reductions in disease burden achieved in the past can be achieved in other cities worldwide. Moreover, sewerage at a large scale is a costly undertaking and even if its role is important, it may not necessarily be the most cost-effective option (Norman et al. 2010).

This may be why the aspect is usually overlooked, in favor of an approach centered on water supply. However, there are studies which suggest that improving sewerage has crucial repercussions on water-related diseases, especially on diarrheal risk, and which show that community sanitation can impact diarrheal disease independently of hygiene measures at household level (Moraes et al. 2003).

Research and Measurement Challenges

The direct link between sewerage (measured usually in terms of coverage) and water-related diseases, although not necessarily straightforward, can usually be estimated, either by means of soil contamination or by means of disease in the population concerned. For example, in a study in Accra, the capital of Ghana, Berendes and colleagues (Berendes et al. 2018), while not directly measuring enteric infections in humans, found a relationship between sanitation

coverage and the concentration of *E. coli* (as an indicator of fecal contamination) in soil and drains. The authors warned however, that the detection of *E. coli* does not distinguish between human and animal sources, which means that potential animal contamination could not be ruled out.

The impact of sewerage interventions at the community (or neighborhood) level is in close relation to the household situation, but public interventions do not take into account the context in which residents live and thus their efficiency is severely hampered. Barreto and colleagues (2007) draw attention to the fact that public sewerage interventions at the neighborhood level will have little or no impact if they are not coupled with interventions or private input to introduce WC's at the household level.

In other words, even if there is a sewerage intervention at neighborhood level, its impact will be limited if there are no interventions (or private investments) at household level to connect households to the network or if locals do not possess a toilet (Barreto et al. 2007). In other words, both the household's connection to sewerage and the neighborhood's sewerage situation (proportion of households connected) can be expected to have an impact on the risk of disease (Norman et al. 2010). However, the relationship between the two levels of wastewater evacuation has not been thoroughly assessed, since in general, literature tackling the impacts of urban drainage on health tends to be rather sparse (Heller 1999). Moreover, in most cities from developing countries in general and in Sub-Saharan Africa and Southeast Asia in particular, sewerage typically serves only the city's business center (Norman et al. 2010).

Debate

The interaction between sewerage at the neighborhood level and the household connection to the public sewer, could explain, at least in part, the inconclusive results obtained by Braga and colleagues (2010) with regard to dengue seroprevalence in three areas of Recife, in Northeastern Brazil.

In another Brazilian city (Betim), sewerage at the household level was not found to have an impact on diarrhea in multivariate analysis (Heller 1999). However, the presence of free waste water flowing in the street augmented twofold the relative risk of diarrheal dis-

ease in children under five (RR: 2.38; 95% C.I: 1.87 – 3.03) (Heller 1999). This would support the hypothesis that inadequate wastewater disposal strategies do not necessarily incur additional risk to the population recurring to them, but to the population downstream. Similarly, the author found that flooding in the lot increased risk of childhood diarrhea in multivariate analysis (RR: 1.39; 95% C.I.: 1.09 – 1.76) (Heller 1999).

Barreto and colleagues (2007) noticed a decline of 22% in the number of days with diarrhea (diarrhea longitudinal prevalence) for children in the Northeastern Brazilian city of Salvador, associated with an intervention aiming to increase the percentage of population connected to the local sewer system from 26% to 80%. The results were even more marked where initial situation was one of high vulnerability, i.e. areas with the poorest sanitary situations, where the decline in the number of days with diarrhea was of 43% (Barreto et al. 2007). However, results might be slightly influenced by the fact that authors did not include, in their analyses, a ‘full model’, to account at the same time for variables relating to household sanitation, water supply and hygiene. Rather, the authors opted for comparing different models, each of which including only part of the variables, grouped in batches. This might lead to not taking into consideration the possible impact of confounders, given that the authors mention adjacent investments being made “in water supply improvements, solid waste management, and institutional capacity building”. These investments, together with the education campaign undertaken to promote hygiene concerning sewerage, could affect results as well.

It seems thus that aspects related to sewerage at the neighborhood level have a non-negligible impact on the risk of. Also, given their strong relationship with sanitation indicators at household level, they could explain, at least in part, results concerning toilet facilities at household level.

Similarly to waste management, sewerage at the neighborhood level will be included in a synthetic variable on neighborhood sanitary infrastructures. This synthetic variable will then be used in the final statistical models.

Proximity to water and vegetation

Context and Mechanism of Action

Wetlands and areas with dense vegetation can pose a potentially significant risk in terms of vector-borne diseases, because mosquitoes tend to search blood meals near their breeding sites, making certain areas more “at risk” than others (Pullan et al. 2010). As a result, while urban malaria and dengue fever are highly diverse in terms of transmission and prevalence, several studies report cases to cluster near mosquito breeding sites (de Mattos Almeida et al. 2007; Deressa et al. 2007; Ghebreyesus et al. 2000; Peterson et al. 2009; Staedke et al. 2003; Sutherst 2004).

Although less prevalent than in rural areas, vegetation is still present in most cities. This fact, coupled with urban farming and market gardens, provides favorable habitats for mosquitoes (V. Robert et al. 2003). Thus, wet areas and urban farming can constitute a risk factor for malaria and dengue infections in children living in Sub-Saharan cities, through human-made water bodies used primarily for irrigation (Ghebreyesus et al. 2000; Matthys et al. 2006).

Research and Measurement Challenges

The main issue with regard to comparability in studies on proximity to wetlands is the distance threshold used. Since different studies use different thresholds, comparing results thus obtained may be hampered. Moreover, the threshold also differs from one species to another, as a function of the maximum and average flight distance. As mentioned earlier, while the flight distance of anophelines can attain up to around 1.6 kilometers, *Aedes* mosquitoes have much shorter flight ranges, usually less than 300-400 meters (Harrington et al. 2005).

Debate

In Ouagadougou, the capital of Burkina Faso, at a distance of 415 meters from a lake, the density of *An. gambiae s.l.* per room decreased by 67% compared with the density observed closer to the lake (V. Robert et al. 2003).

Proximity to (fish) ponds can also increase the risk of mosquito-borne diseases (Elston 2005), since the former constitute stagnant

waters in which the vector breeds (Braga et al. 2010; Keiser et al. 2005; Peterson et al. 2009). Irrigated fields and lands around swamps can constitute a source of humidity favorable to mosquitoes (Keiser et al. 2005; Koram et al. 1995b). Certain cultures such as rice paddies favor the accumulation of water, especially during rainy seasons, which was associated to higher risks of malaria transmission (Koudou et al., 2005, cited by Matthys et al. 2006). This hypothesis was supported by Ghebreyesus and colleagues (2000), who found that the use of irrigated lands by the family was associated with a higher risk of malaria for their children. The risk increased 2.68 times (95% CI: 1.64 – 4.30) in children whose families owned irrigated lands, compared to those whose families did not. The authors interpreted this finding by the fact that usually the households are located close to the fields owned, thus making the household members more at risk (Ghebreyesus et al. 2000). Their results are concurrent with those obtained by Pullan and colleagues (2010), who studied risk factors of *Plasmodium* infection in Eastern Uganda. The authors found that living more than 750 meters from a rice-growing area was a factor limiting the risk of malarial infection.

However, the results obtained by Clarke and colleagues (2002) show that, while being protective of infective mosquito bites (and thus of parasitemia), living in a village located 3 or more kilometers away from the rice-growing wetlands was not significantly associated with lower levels of – concurrently – fever and parasitemia, of less high-density (5000 or more per μL) parasitemia or of less prevalence of severe-to-moderate anemia. Also, among the parasitemic children, those living in villages further from the vector breeding sites were twice as likely to develop clinical malaria, than children of the same age group, living in lower transmission villages (Clarke et al. 2002). The authors hypothesize that this finding is likely to be due to a delayed acquired immunity in children living in hypo-endemic areas. The concept refers to the fact that individuals living in areas with higher malaria prevalence, being on average exposed to more episodes, develop immunity to the parasite at an earlier age than individuals living in areas where malaria is rarer. This could mean that children living in hypo-endemic areas are at greater risk of malaria morbidity, while being at lower risk of malaria infection (Clarke et al. 2002). The delayed acquired immunity in children liv-

ing away from vector breeding sites means that the type of residence area also influences the age pattern of clinical malaria incidence. Using 3 kilometers from a mosquito breeding site as threshold, the authors found that in children living closer to the mosquito breeding site, the risk of clinical attacks decreased by the age of 3 years, as opposed to children living further away. This finding confirms similar results obtained in Senegal (Trape et Rogier, 1996, cited by Clarke et al. 2002), comparing clinical malaria cases in two villages, exposed to 20 and 200 infective bites per person per year.

Water bodies used for agricultural purposes, such as ponds and fish ponds can constitute risk factors for mosquito-borne diseases as well. In the town of Man in Côte d'Ivoire, a study on urban farmers and their families found that children below 15 years old, residing 500 or more meters away from ponds and fish ponds were at 0.25 the risk of presenting *Pl. falciparum* infections, compared to those residing within 100 meters (95% CI: 0.05 to 0.72) (Matthys et al. 2006). Concerning parasitemia though, (the concentration of parasites in the blood), the authors found no significant increase associated with proximity to ponds and fish ponds (Matthys et al. 2006).

Similarly, a study conducted in an area of the city of Adama (Ethiopia) assessed the impact of proximity to an agricultural vector breeding site on *Pl. falciparum*, *Pl. vivax* and mixed infections (Peterson et al. 2009). The site was 500 meters to a flood plain used as watering hole for cattle during the heavy rains (July to October) and for crop cultivation from January to October. Using a multi-level model, the authors found that increased distance to the vector breeding site provided protection against *Plasmodium* infections in children. Gradually diminishing with increase of distance, the infection rate tended towards zero, past the 750 meter used as threshold in the study. Furthermore, 79.38% of the between-household variance in terms of malaria infections in children was explained by house proximity to the major vector breeding site (Peterson et al. 2009).

Other types of water bodies, such as those created by dams or canals, have also been reported to increase mosquito presence. An aggregate analysis, comparing villages on the criterion of proximity to dams, found a sevenfold increase in the risk of malaria in villages

and houses located close to and downstream from the dam (Ghebreyesus et al. 2000). Similarly, Fobil and colleagues (2012) found that the hotspots of mortality due to malaria in Accra (Ghana) were distributed more-or-less radial around to the city's western lagoon.

Results at the individual level confirm the association: Guthmann and colleagues (2001) analyzed clinical malaria in a coastal region of Peru, in relation to the number of canals within 200 meters of the household. The authors found significant negative relations, using no canal as reference category and bivariate analyses: one canal was associated with 1.87 times the risk of developing malaria (95% CI: 1.38 – 2.55), while more than one canal augmented the risk by 2.13 times (95% CI: 1.34 – 3.40). Distance to other breeding sites did not attain statistical significance, but living more than 200 meters of a canal was – in multivariate analysis – significant at 95% CI, with a 0.27 to 0.57 reduction of malaria risk, compared to living less than 100 meters from a canal. Furthermore, larva collections showed that canals were good breeding sites for *Anopheles* species, causing higher vector density in areas situated close to canals (Guthmann et al. 2001).

Non-anthropogenic water bodies (such as marshes) and streams are less prevalent in cities than in rural areas. However, if present, they also represent potential breeding sites for mosquitoes. Especially in rainy seasons, when they pose risk of overflowing, swamps and freshwater pools were often found to increase the risk of dengue and malaria transmission (de Mattos Almeida et al. 2007; Nahum et al. 2010). In Senegal's Pikine area, located just outside of Dakar, niayes (small, freshwater lakes and swamps in dune depressions) were found to play a significant role in the presence of *Anopheles* mosquitoes. Adult female *An. arabiensis* mosquitoes were much more likely to be caught around niayes (up to around 300 meters), than further from them, following a decreasing gradient tendency (Salem 1998). This association was observed both during dry and wet seasons.

Although not approaching directly disease infection, Konradsen and colleagues (2003) found that, among 7 villages studied in a dry zone of Sri Lanka, there were clear differences among the villages in terms of presence of *An. culicifacies*. Houses from villages near the

stream appeared to have higher densities of mosquitoes than those in the villages farther away. Compared to houses located at least 750 meters away from the stream, those located closer had a risk 4.7 times higher of having *An. culicifacies* and 1.5 times higher for *An. subpictus* (Konradsen et al. 2003).

In a longitudinal study on Ugandan children from the Kawempe division of Kampala, Staedke and colleagues (2003) found that the risk of being diagnosed with malaria was also positively associated – both in univariate and multivariate analysis – to living near a stream or a swamp. The latter was defined as a low-lying area with frequent standing water, particularly in times of steady rainfall.

Controlling for other potential risk factors, the fact of residing 500 meters or less from a stream (as opposed to 500 meters or more) resulted in an almost twofold increase in the incidence rate ratio (95% CI: 1.2 – 3.1). Similarly, a distance of 1 to 100 meters or less than 1 meter from a swamp were, compared to a distance of more than 100 meters, associated with sharp increases in the incidence rate ratio for malaria in children (95% CI: 1.2 – 4.7 and 2.6 – 6.9 respectively) (Staedke et al. 2003).

Also, in a study in the Dakar area of Senegal, *Plasmodium* incidence in blood samples was positively associated with exposure to the breeding sites: in an area of Pikine, children who lived between 10 and 160 meters away from marshlands experienced on average one infection each year, while children living between 785 and 910 meters away experienced one infection every 4 to 5 years (V. Robert et al. 2003).

According to the results obtained by Staedke and colleagues (2003), *Anopheles* may prefer stagnant waters over flowing ones: the distance to a swamp/marsh and the distance to a stream were independent predictors for clinical malaria, but distance from a swamp was a stronger predictor. This could be explained by the fact that swamps – as opposed to streams – are relatively large and permanent bodies of water, therefore providing a more stable environment for mosquitoes to breed (Matthys et al. 2006). Similar results were obtained in a cross-country study in six Asian cities (Arunachalam et al. 2010). The study used *Aedes* pupal counts as proxy for adult

dengue vectors and found a significantly greater occurrence in water recipients that had not been used in the previous seven days.

However, results of a univariate analysis on clinical malaria in the semi-urban region of Nouna (Burkina Faso) show no significant difference depending on proximity to the major water source. Nevertheless, as the authors acknowledge, it was primarily due to the low number of cases per category (Yamamoto et al. 2010), that the confidence intervals were very wide and it may be possible that thus the association did not reach statistical significance.

Thus, data from most studies seems to conclude that distance to a breeding ground (most usually a stagnant water body) poses a significant risk with regard to mosquito-borne diseases, most notably malaria. This is most likely because *Anopheles* mosquitoes prefer to breed in natural water bodies, while *Aedes* mosquitoes breed usually in water containers found around households. However, there does not seem to be a consensus with regard to the threshold distance that significantly increases the risk of infection. Given this lack of consensus on the threshold for proximity to wetlands and given data availability, I will use the presence of a water zone, in the form of canals in the neighborhood, in order to specifically assess their potential impact on mosquito-borne diseases.

Climate

The role of climate-related aspects has been relatively less studied, compared to that of factors pertaining to the immediate environment. While the relationship between seasonal changes and peaks of diarrheal incidence have been reported, most studies have not controlled for potential confounding factors (Hashizume et al. 2007) and hence, the role of climate has also not been clearly elucidated in the transmission of enteric protozoa (National Research Council 2001). Similarly, the relationship between absolute mosquito abundance and an exhaustive multivariate network of climate factors has not yet been established (Arunachalam et al. 2010; Rogers and Randolph 2000), although climate factors are known to be a fundamental issue in determining vector-borne disease epidemics (Hales et al. 2002).

Certain meteorological variations can affect both the pathogens and

– in the case of mosquito-borne diseases – the transmission vector (Béguin et al. 2011; Rowley and Graham 1968). The latter is influenced both with regard to density and to efficiency, particularly in terms of breeding, growth rate, lifespan and flight capacity (Deubel and Rodhain 1999; Rowley and Graham 1968).

Recently, in the context of increased greenhouse gases that may lead to an increase in average temperature and changes in the hydrological cycle (Sankoh and Ye 2011), some modifications may occur in terms of vector borne diseases' spatial distribution and duration of epidemics (Deubel and Rodhain 1999; National Research Council 2001; Patz and Reisen 2001). Several models, using exclusively climate variables, have satisfactorily explained the current spatial distribution of both malaria and dengue (Campbell-Lendrum and Reithinger 2002).

Given that both the quantitative and qualitative data used in this research do not include large variability with regard to climate (temperature, rainfall and altitude), given that it has been collected in the city of Dakar during the rainy season, I will not include climate variables in the current analysis. However, in pursuance of a literature review that is as comprehensive as possible, I considered the inclusion of climate factors to be useful in the present synthesis of potential risk factors. Therefore, I will briefly state what existing literature has to say on the topic of climate factors and of their potential impact on water-related diseases.

Temperature

Temperature is one of the most important factors in determining whether a geographic area is prone to infectious diseases and to the type of prevalent infectious diseases. This is because temperature influences both the types of pathogens and the potential vectors involved in transmission (Deubel and Rodhain 1999). In this context, a study using maximum likelihood methods modeling, has indicated that the minimum of the mean temperature may be the single most important predictor in the distribution of malarial infection in the future (Rogers and Randolph 2000). Similarly, Béguin and colleagues (2011) found the mean temperature of the coldest month to be one of the main climatic predictors of the occurrence of malaria as an infection.

Higher temperatures generally favor growth in pathogens, adult survival and parasite maturation within the mosquito (Ye et al., 2008, cited by Sankoh and Ye 2011; Singleton et al. 1982). Studies looking at various diarrheal pathogens, such as cholera and *E. coli* have consistently reported an increase in growth speed at higher outside temperatures, whereas in surveys carried out in winter, during low outside temperature, the occurrence of the pathogens studies was significantly reduced (Shaw et al. 1971; Singleton et al. 1982). A laboratory study found that increasing water temperatures up to 30° C had a pronounced effect on the multiplication of *Vibrio cholerae*, the pathogen involved in cholera (Huq et al. 1984).

In a time-series analysis on non-cholera diarrheas in Bangladesh, Hashizume and colleagues (2007) found that, adjusted for season, between-year variations and rainfall, there was a linear and positive association between temperature and diarrheal cases. Thus, for a one degree increase in temperature (taking into account the incubation period), cases increased on average by 5.6% (95% CI: 3.4 – 7.8) (Hashizume et al. 2007). For cholera cases, the increase was even more marked: a study in Zanzibar (Tanzania) found that a one degree increase in temperature, at 4 months lag, resulted in a doubling of cholera cases (Reyburn et al. 2011). The same positive relationship was found in the capital of Bangladesh, Dhaka, in a study that looked at the daily number of diarrhea patients (classified as *V. cholerae* or Rotavirus) for 22 years, between 1980 and 2001 (Teshima et al. 2004).

In the case of mosquito-borne infections, an average dengue incubation period of 12 days at 30° C is reduced to only seven days, at 32-35° C (Deubel and Rodhain 1999). However, development ceases when temperatures drop, an aspect which also concerns malaria. Studies are generally consistent in their findings with regard to the minimum level below which the *Plasmodium* parasite cannot develop in the mosquito host. Thus, Chaves and Koenraadt (2010), mention this threshold to be situated at around 15-16° C. Patz and Reisen (2001) distinguish between *Pl. vivax* and *Pl. falciparum*, the first developing at temperatures above 15° C while the second requiring a minimum of 18° C.

Secondly, temperature influences the vector in terms of development, survival and behavior. In general, warmer climates shorten

the pupal stage, thus accelerating larval development (Christophers, 1960, cited by Padmanabha et al. 2010; Sankoh and Ye 2011). In the case of *Aedes* mosquitoes, the minimum temperature necessary for larval development is approximately 15° C (Rueda et al, 1990, cited by Hayden et al. 2010).

Several studies have shown that ambient temperature is also critical to adult survival, since in cold climates, mosquitoes are unlikely to survive long enough to become infectious (Hales et al. 2002). Higher minimum temperatures in Uganda were associated with an increase in the malarial vector density in the highlands (Sankoh and Ye 2011). However, too high temperatures reduce mosquito life expectancy (Malakooti et al. 1998) and laboratory studies have shown that at over 40° C, the life expectancy of *Aedes* mosquitoes is reduced significantly (Deubel and Rodhain 1999).

The combination between mosquito survival and parasite development results in the proportion of mosquitoes that survive long enough to become infected. The latter was found to be highest between 28 and 32° C (Craig et al, 1999, cited by Chaves and Koenraadt 2010).

With regard to vector behavior, the main two aspects concerned are flight efficiency and biting patterns. The optimal temperature for mosquito flight occurs between 15 and 32° C, although general flight performance was found to be greater below 27° C (Rowley and Graham 1968). An increased temperature shortens the interval between blood meals for female mosquitoes, from 4 days at 19° C, to only 3 days at 21° C (Malakooti et al. 1998).

Similarly, higher temperatures favor the proliferation of diarrheal pathogens, which increase the risk of infection (Teshima et al. 2004). A link was found between the temperature of the surface of sea in the Bay of Bengal and the number of cholera cases reported in Bangladesh (Colwell, 1996 National Research Council 2001). This link between higher temperatures and higher diarrheal transmission was later confirmed by Pascual and colleagues (2000, cited by National Research Council 2001) in an 18-year time-series analysis of cholera records from Bangladesh.

Rainfall and humidity

The role of rainfall in water-related diseases is somewhat less constant across studies, when compared to that of temperature (Hashizume et al. 2007). The general starting point in literature is that excess rain leads to floods, which can provide good development conditions for both diarrheal pathogens and mosquito larvae, thus increasing both the risk of contamination or of mosquito bites.

Concerning diarrheal episodes, correlations have been found between increased rainfall and increased oocyst concentrations of certain enteric protozoa in river waters (Alterholt et al., 1998, cited by National Research Council 2001). Higher rainfall has also been linked to outbreaks of protozoan diarrheal episodes (Weniger et al., 1983, cited by National Research Council 2001).

Looking at routine cholera surveillance reports between 1997 and 2006 in Zanzibar (Tanzania), Reyburn and colleagues (2011) found that an increase of 200 mm of rainfall at 2 months lag was associated with an increase, of 1.6 times, in cholera cases. They also found a significantly positive association between rainfall and temperature, with regard to cholera, at a 1 month lag (Reyburn et al. 2011).

Hashizume and colleagues (2007), in an analysis on non-cholera diarrhea cases in Dhaka, Bangladesh, from 1996 to 2002, found the same relationship between high rainfall and diarrheal incidence: the study noted an increase in cases in both the wet and dry seasons, at a lag of between 0 and 16 weeks.

In the case of malaria, Béguin and colleagues (2011) found the mean precipitation of the wettest month to be among the main climatic predictors of the occurrence of malaria as an infection. Malakooti and colleagues (1998) studied malaria incidence retrospectively in the Kericho tea-growing highlands of western Kenya, for a period covering 8 years (1990-1997). The authors used data provided by the local tea company: cases were identified using the hospital monthly reports, while temperature and rainfall data were available for the years 1971 through 1997. No change in climate was shown to explain malaria variations and the authors gave a possible lack of sensitivity of the climate-related data as a potential explanation for this lack of association.

However, Arunachalam and colleagues (2010) found a positive temporal association between rainfall and the number of laboratory dengue cases in a multicountry study performed in six big Asian cities, which analyzed both intradomestic and public breeding spaces.

With regard to dengue, several studies have shown no clear relationship between rainfall variations and disease incidence. This could be due to the fact that the *Aedes* mosquito prefers to reside indoors and breed in man-made water bodies, which could also explain the presence of dengue in an arid climate like Saudi Arabia. Aziz and colleagues (2012) studied mosquito abundance and dengue incidence in Makkah City during 12 months, from April 2008 to March 2009. The authors found that *Ae. aegypti*, although more abundant during the rainy season, were present throughout the one year study period. A reason for this could be that, in the case of draught, water is often stored in recipients inside the compound, which favors vector breeding (Aziz et al. 2012; Deubel and Rodhain 1999).

Similarly, entomologic investigations performed in the Kedougou area of Senegal in June, October, and November 1999 found a similar lack of association with dengue emergence (M. Diallo, Ba, Sall, et al. 2003). The authors calculated rainfall variations by subtracting the recorded seasonal rainfall from the seasonal rainfall mean of 1961 to 1990 and used monkey DENV-2 serum sampling as outcome variable, given that DENV-2 circulates regularly in mosquito, human, and monkey populations (M. Diallo, Ba, Sall, et al. 2003). Results showed no significant seasonal variability, DENV-2 amplifications being detected during both periods of heavy rainfall and during periods of low precipitation.

With regard to humidity levels, while they too have been shown to affect the life span of the adult mosquito, which would imply variations in malaria transmission, a study performed in the highlands of Uganda found humidity levels to not play a significant role in disease risk (Lindblade et al., 2000, cited by Sankoh and Ye 2011). Concerning mosquito behavior, Rowley and Graham (1968) found that relative humidity only played a significant role on female mosquitoes' flight performance at high temperatures of 32° C, where a humidity level of 30% had a marked effect of limiting flight

performance.

Altitude

Although sometimes cited as a factor for vector-borne diseases, altitude may, in certain cases, be just a proxy for temperature. Temperature is crucial to both mosquito and parasite development, and an increase of 100 m in altitude is associated with an average decrease of 0.6°C in temperature (Strahler, 1973, cited by Chaves and Koenraadt 2010; Patz and Reisen 2001). This makes it possible for vector-borne diseases to infect humans at high elevations, provided that other conditions, regarding rainfall and – more importantly – sufficiently high temperature – are met. Thus, malaria outbreaks have been observed even at altitudes of 2000 meters, when the mean monthly temperatures were above 18°C and rainfall was higher than 15 cm^3 per month (Malakooti et al. 1998). Given that the mosquito vector can be found at altitudes reaching up to 3000 meters, possibly the only real limiting factor for malaria transmission is the survival of the *Plasmodium* parasite (Malakooti et al. 1998).

4.3 To Sum Up

To briefly summarize the information contained in the previous pages, I have firstly covered the main characteristics of both diarrheal and mosquito-borne water-related diseases. While their causes and clinical symptoms often differ, the pathway of transmission is a common one – water (which is ingested or which serves as breeding ground for vectors which transmit the disease). The different scales of measurement (and the comparability issues that may arise) also constitute a notable aspect that has been tackled.

Secondly – and probably most importantly for the current research – a rather in-depth review of the potential risk, protective and potentially influencing factors in general has been laid out. In light of the current literature, several aspects emerge.

The first one is the wide and diverse range of potential causal factors. Moreover, they do not seem to operate on solely one level, but may impact the individual, his or her family and household, the

area where he or she lives and the wider climatic conditions of the area. It thus becomes clear that, although the process of transmission seems fairly straightforward, water-related diseases are multifaceted infections, with no single determinant.

The second aspect is that several potential interactions may occur between determinants and, although this has been less studied, potentially between levels of analysis. Behaviors may be influenced by the environment and the environmental aspects themselves may interact, at different levels of analysis. Since literature on this topic seems somewhat sparse, this particular feature will be tackled more in depth in the current research.

The third aspect refers to the discrepancies in terms of existing research on the mechanism of action and potential impact of various determinants: while some – such as the access to water – have been studied in depth and the corpus of scientific literature on them is fairly well established, others – such as health literacy – have constituted the topic of a very limited number of studies. Moreover and for many of the potential determinants, there seems to be little consent as to their impact, despite the sometimes abundant literature on the subject.

In this context, it seems useful to address the aforementioned aspects, using an integrated approach, which may offer more insights into the diverse pathways of transmission of water-related diseases in urban children.

Chapter 5

Analytical Framework

This chapter sets forth the strengths and limitations of the available literature on risk factors for childhood water-related diseases in urban areas and makes the case for the current study, by presenting the scientific gaps it helps fill. Subsequently, it discusses the main research questions the study aims to address, as well as the hypotheses formulated and the starting points of the project.

5.1 Context of the Current Study

5.1.1 Age

Younger children constitute a particularly fragile category of population, especially in terms of infectious diseases (Mendez et al. 2000; Simon et al. 2015). Therefore, most studies in general, and especially those from Sub-Saharan African contexts have focused on young children, usually under one or under five years old. There is thus less information with regard to the etiology of disease and the health determinants of children older than five (Sambe-Ba et al. 2013). However, as children get older, the risk factors they face may be different, due to the lack of the protective effect of breastfeeding, to their increased independence – which could increase their exposure to pathogens – and to changes in their immune responses, which modify their susceptibility to disease.

This situation occurs in the context of existing literature – by and

large – agreeing that age influences the patterns of transmission of infectious diseases. However, since at the same time most studies focus on (very) young children, the current research aims to add information on what the risk and protective factors are for children past the age of four, looking at those aged two to ten.

5.1.2 Location

Aside from focusing almost entirely on very young children, research conducted on the factors favoring the transmission of water-related diseases more often concerns rural settings, with more recent developments on urban areas. However, with regard to water-borne and vector-borne diseases (malaria in particular), the risk factors in urban areas may be different than those identified in rural areas. This means that, albeit the increasing attention that urban health has been getting since the beginning of the century, as the majority of previous studies had been carried out in villages, relatively less is known about the factors that make some persons living in a city more likely to become infected than the average city dweller (Mendez et al. 2000; Sambe-Ba et al. 2013).

Moreover, the beginnings of urban health research have most often employed the approach of contrasting cities to their rural counterpart (United Nations Human Settlements Programme 2006). Hence, the effect of the area is often measured in terms of rural-urban differences, rather than intra-urban effects. As a result, cities tend to be studied as one homogeneous unit and through their opposition to rural areas. In this line of thought, a large body of literature on rural-urban health differences have tended to focus mainly on the fact that cities appear to be a favorable milieu to health, largely thanks to the better provision of medical and sanitary infrastructure (Bocquier, Madise, et al. 2011).

However, such an approach fails to take into account factors which may influence different parts of the same city in different ways and thus may give way to bias. This is because particularly in terms of pathogen transmission, urban areas are different not only from their rural counterpart, but also among themselves. The fact that cities are more densely populated has an important impact on infectious

diseases and their clustering patterns. Firstly, due to the large portion of built space, the amount of potential transmission areas is significantly diminished. Secondly, in the case of vector-borne diseases, the high human density means that one individual's risk of infection at one given moment decreases proportionally (V. Robert et al. 2003).

However, this also means that certain areas concentrate most of the risk of water-borne diseases, areas whose populations experience significantly higher-than-average risk, due to their socio-economic composition, their access to infrastructures or the environment. Hence, the specific living conditions and health risks of certain categories of the urban population may be far worse than in rural areas (Lall and Deichmann 2009). This is often the case in slums and peri-urban areas, largely due to fast and often uncontrolled urbanization, which means that settlements are sometimes located in precarious areas. Thus, to the social vulnerability of the often poorer and less educated inhabitants, is added the environmental vulnerability of hazardous living conditions (Pelling, 2003, cited by Borderon 2016; Lall and Deichmann 2009). In this sense, urban areas are particular in terms of environment, social composition, access to infrastructures and, thus, exposure to pathogens. As a consequence, the factors which influence the risk of transmission of water-related diseases are – at least in what concerns the environment – different between urban and rural areas and sometimes even from one part to another of a territorial division, which implies that the analysis must be specific and contextualized to the area of study. Moreover, with regard to mosquito-borne diseases in general and to malaria in particular, another aspect to be noted is that the lower exposure in cities leads to a delayed acquired immunity which, in turn, can lead to complications and severe forms of the pathology in older children, who would normally have acquired immunity in an endemic area (Borderon 2016). This comes as, until recent decades, *Anopheles* mosquitoes were considered to not breed in urban areas (artificial or polluted waters), thus rendering urban transmission highly unlikely. However, more recent studies have shown that is no longer the case, thus adding malaria as an urban health issue (Pages et al. 2008).

5.1.3 Approach

The approach of studying intra-urban differentials has yielded more recent literature, but which often still faces challenges. Although an approach which has been criticised in recent years, many studies looking at the impact of the area on individual health still content themselves with aggregating individual-level indicators and using these as characteristics of the area (Harpham 2009). In other words, inferences about the outcome in individual health are deduced from inferences about the group. In this case, translating the results into determinants at the individual-level poses a real risk of ecological fallacy and may lead to erroneous conclusions. Another one of the main challenges in research looking at neighbourhood effects is identifying true causal effects and mechanisms: in many cases, analyses which do take into account the characteristics of the area itself, fail to look at causation and limit themselves to “correlations between individual outcomes and neighbourhood characteristics” (van Ham et al. 2012, p. 3).

Yet another challenge arises from the choice of determinants to study. Often, research tends to either ignore the effect of the area or focus entirely on it, not taking into account, for instance, behavioral aspects or wealth. This choice, is frequently the result of either data availability limitations or of methodological constraints. On the one hand, often times surveys either focus on the behavioral sphere or on the environmental one, whereas data integrating several aspects of life are less common, as they require larger-scale studies. On the other hand, at least until the last two decades, software capabilities imposed methodological limitations, which made it difficult to assess the relative effect of both the individual and the area (Mauny et al. 2004). Since individual characteristics are easier to measure, while environmental factors and their relative impact lends itself less easily to quantification, studies may tend to leave aside the role of the immediate area, in favor of an individual-centered approach.

On that account, possibly the most fundamental challenge faced by existing literature on child health in general and on infectious diseases in particular, is treating childhood health conditions as unifacted and unicausal phenomena. Thus, “child health status is a multidimensional concept that often is translated into and con-

fused with very narrow, one-dimensional indicators” (Palloni 2006, p. 590). But more often than not, childhood illnesses are a result of the interaction between determinants from several spheres at various levels, so compartmentalizing the study of determinants and focusing entirely on specific disease mechanisms risks overlooking potentially fundamental links (Mosley and Chen 1984). Hence, treating infectious diseases as single-cause phenomena and only focusing on one aspect, be it related to water supply or to transient factors (such as eating patterns and temporary absence of the mother from home) increases the risk of confounding factors and impedes comparison (Bukonya and Nwokolo 1990; Fewtrell and Colford 2004).

While it is becoming more and more apparent that childhood infections have multifactorial sources and that many risk factors are generally involved, analyzing and decanting risk factors one-by-one can sometimes prove less obvious. In many cases, these factors interact and influence each other, as several studies have mentioned multiple interactions between aspects of the household or of the area (Dos Santos and LeGrand 2007; Seigel et al. 1996).

Hence, improving urban health in general and managing urban childhood water-related diseases in particular depends on a comprehensive understanding of the complex web of determinants and their inter-relations. In the past couple of decades, scientific literature has started to also look at neighborhood effects when it comes to health (van Ham et al. 2012). However, while it is easier to envision how the environment may impact on health, more research into the relationship between behavioural factors and environmental health is needed (Harpham 2009).

In other cases, such inter-relations were detected across several levels of analysis, as is the case of socio-economic and education variables (which relate to the household) and environmental factors of the area (Fewtrell and Colford 2004). Jalan and Ravallion (2003) draw attention to the fact that, most often, the impact of public investments and facilities are mediated by parental inputs. Thus, the same facilities will benefit children differently, by means of the interaction with parents’ education and sanitary knowledge : if the facilities and parental inputs are in a situation of cooperation (better facilities are complemented by higher parental involvement), the

outcomes are likely to be much higher than if the two are in a situation of substitution (facilities 'make up' for the lack of parental involvement).

Another aspect which arises with regard to water-related diseases is that of co-morbidity. Experiencing several water-related conditions, occurring together or within short duration from one another, increases the risk of complications and the cost of care. As a result, some topics have constituted the focal point of literature on the sphere co-morbidity, mainly due to their impact on prediction and treatment (Valderas et al. 2009):

- what are the conditions which may co-occur and the factors which favor them
- the importance of each condition in relation to the other(s)
- the sequence in which the co-morbidities occur
- the burden of co-morbid diseases

Although the current study does not focus specifically on co-morbidity, it will look at the possible common determinants for diarrheas and vector-borne fevers, as well as to risk factors which are specific to each type of infection.

5.2 Research Questions, Hypotheses and Procedure

While much of the existing body of literature on urban health has focused on the rural-urban differences, the current study pursues identifying intra-urban differences, a perspective which complements the more developed rural-urban and inter-urban ones. More recent innovations in statistical methods and software have enabled researchers to look at multilevel determinants of health (Ompad et al. 2007). This means that, while existing data on intra-urban disparities and the impact they have on disease transmission is, for now, somewhat limited, "the growing disparities within many cities are fertile ground for investigation" (Vlahov and Galea 2002, p. S8).

In light of what previous pages have summarized from existing literature on childhood infectious diseases, it becomes undeniable that looking at the determinants of water-related diseases in urban areas needs to take into account both individual characteristics and community-level factors and thus has to be done in a multilevel way (Harpham 2009).

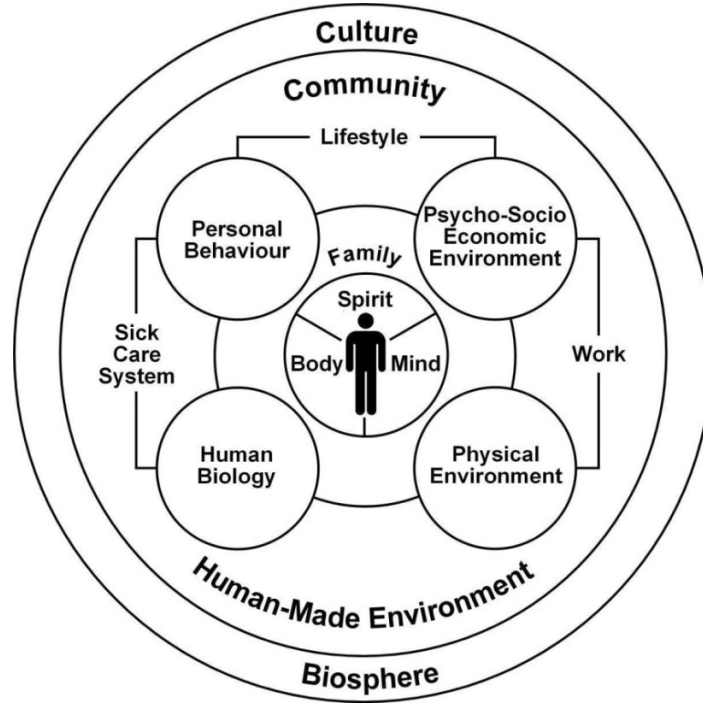
A challenge linked to multilevel models though, is that they typically mobilize a large number of indicators, which increases the risk of multicollinearity and makes the results of statistical models difficult to interpret or which run the risk of overfitting the higher levels. This is why, often, studies have selected a very limited number of explanatory variables to focus on (Mauny et al. 2004; Peterson et al. 2009). However, such an approach raises the issue of omitting potentially significant determinants or confounding factors, hence creating an either partial or biased view of the disease transmission process.

For these reasons, the current research models data on symptoms of water-related diseases by adding random intercepts at the higher levels of the analysis. Moreover, it employs techniques of dimension reduction, by means of Latent Class Analysis (LCA), which are appropriate for use with categorical indicators. By doing this, it can include a relatively large amount of explanatory data from different spheres of life, all while avoiding the caveats of a very large number of covariates.

The focus on both behavioural factors and environmental ones as well as on the possible links between them requires a general framework which comprehensively integrates these spheres. Consequently, the study's analytical framework draws to a certain extent from "The Mandala of Health", a term coined by Hancock in 1985 (Figure 5.1).

The relatively straightforward representation distinguishes between community and environment in determining health outcomes and identifies four main spheres of factors: the behavioral one, the societal one, the biological one and the physical environment. While the concentric circles represent different layers (the individual, then the family, then the community and its environment and finally, the wider concepts of culture and biosphere), the four circles represent

four spheres of life which interact to determine health outcomes in the individual. They comprise biological characteristics, behavioral factors and the socio-economic status, as well as the natural and man-made environment.



Source: Hancock 1985, reprinted by Coutts et al. 2014

Figure 5.1: The Mandala of Health

While several other frameworks are available for studying health in general and child health in particular, I have opted to create the analytical framework for this research based on the Mandala of Health for several reasons.

On the one hand, most existing frameworks, such as the Country Health Rankings Model (University of Wisconsin Population Health Institute 2014), list potential spheres of determinants to child health (such as the socio-economic, the behavioral or the environmental one), but do not account for or take an interest in the inter-relations between these dimensions. Since the aspect of potential links between spheres of determinants was one of the key

research questions of this study, this type of framework was not an optimal choice in this case.

A seminal work by Mosley and Chen (1984) yielded one of the most influential frameworks in the recent study of child health. While the Mandala of Health and Mosley and Chen's framework share many points in concept, I have opted for the first one for two reasons. Firstly, while Mosley and Chen's framework analyzes child health in the form of a continuum, looking at variations on this scale, the present study focuses on a binary question, of whether or not the child experienced a morbid episode. Secondly, I estimated that the Mandala of Health better stresses and thus offers a clearer picture of the two aspects this study is focusing on: behavior and environment. Although present in the framework proposed by Mosley and Chen, they do not occupy a central position, whereas the Mandala of Health has a visual advantage in this regard.

Since studying a multidimensional phenomenon requires an approach which respects this multidimensionality, the analytical framework of the current study draws from the Mandala of Health, with a multilevel conceptualization focusing on the two spheres of interest in this study and taking three levels of analysis into consideration. By developing this hierarchical component, determinants are nested in a structure which groups the individuals into households, which themselves are grouped into neighborhoods (Figure 5.2).

At the level of the individual, the framework considers the child itself and their primary carer. Regarding the child, of interest are the demographic characteristics, which constitute the biological grounds determining both vulnerability and exposure to pathogens. Regarding the child's mother or carer, aside from demographic characteristics, the socio-economic status is used as control factor in the analysis. Concerning the child's family and dwelling, health-related knowledge, attitudes and behaviors, the family's wealth and the domestic facilities influence the child's exposure to pathogens. In the immediate area, factors pertaining to the natural and man-made landscape, as well as possible influences from neighbors and the area's sanitation level are also considered.

The mechanism of action of these determinants may be either by

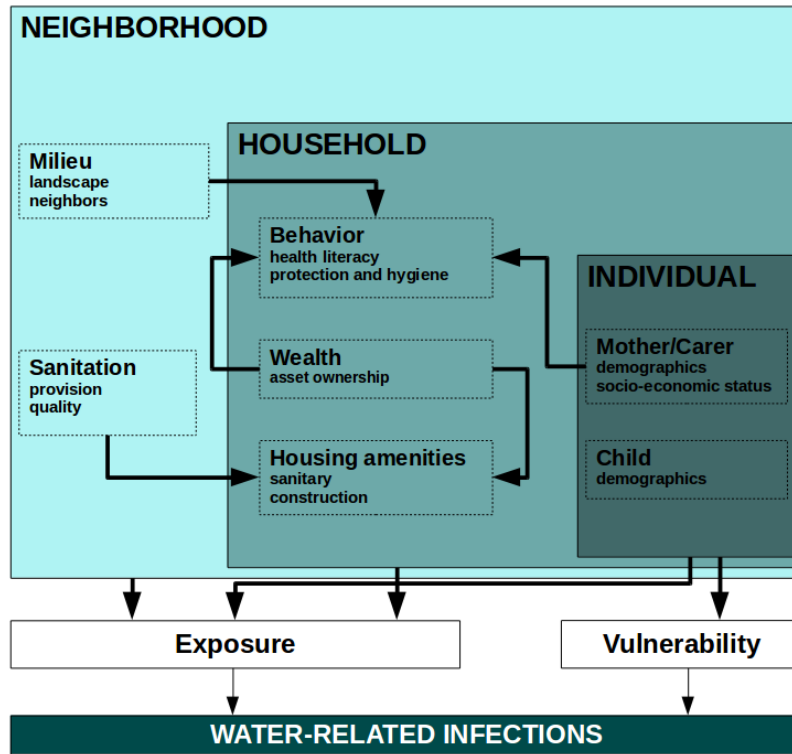


Figure 5.2: The Analytical Framework of the Study

favoring/impeding contact with the pathogens (exposure) or by impacting on the individual's susceptibility of developing the disease, when coming in contact with the pathogen (vulnerability). Thus, the concepts of "exposure" and "vulnerability", in this context become similar to that of "proximate determinants" proposed by Mosley and Chen (1984).

Several possible relationships between determinants are taken into account and represented as links between spheres in Figure 5.2, on account of existing literature (See Chapter 4):

- The mother's/carer's socio-economic status is likely to have an impact on her behavior, either in terms of hygiene and prevention or in terms of childcare choices. For this reason, both aspects need to be accounted for in the analysis and measures of the primary carer's socio-economic status will be used as control variables.

- The family's financial situation will probably also impact on their propensity to adopt certain protective measures or influence their options for childcare. Thus, in order to distinguish the role of behavioral factors from that of socio-economic ones, household wealth will also be taken into account as control variable.
- Moreover, household wealth may also influence the general facilities in the dwelling, thus potentially also impacting aspects pertaining to the sphere of the immediate environment.
- A link to which Heller (1999) hints is that between sanitation facilities in the household and those of the area. Hence, I assume that the overall sanitation in the area will determine, to a certain extent, both the type of facilities in the dwelling and their potential challenges.
- One of the main objectives of this study is to look at the role of behaviors and environment in water-related diseases. In doing so, I am making the assumption that certain characteristics of the area, such as the presence of water bodies or the sanitation infrastructures, will influence the way their inhabitants behave. Thus, similar people living in different areas may well act differently, in terms of health and disease protection.

In this context, the current study aims to unravel this web of determinants for water-related diseases – water-borne and mosquito-borne – in children from Dakar. The goal is thus to differentiate the role of each sphere and level, investigating which characteristics of the child, of his/her family and of the milieu influence the occurrence of a water-related disease episode. For this, based on the existing literature dealing with water-related diseases in children, the main hypotheses which provide the starting point for the analysis are:

1. Given the numerous potential risk and protective factors mentioned by existing literature, as well as the debates surrounding most of them, I am expecting that a relatively large network of weaker determinants – pertaining to several spheres and levels (individual, family, area) – concur to determine water-related disease outcomes, rather than a small set of

strong determinants.

2. Given the diverse environment of Dakar, I am expecting a certain amount of clustering of the cases, with a few neighborhoods having high incidence and a few neighborhoods having low incidence of water-related diseases. However, despite this variability at the higher levels, the existing body of literature suggests it is still the lower levels (the child and the primary carer) which will contain most of the variability in terms of outcome. In other words, the level of the individual will probably have a stronger impact than the higher ones (the dwelling and the area where it is located).
3. Despite potentially different pathways of transmission, I am expecting that most determinants and risk factors are similar for both types of disease (water-borne and mosquito-borne). Although both types of outcome have not frequently been studied together, existing literature on either one of them often points, albeit sometimes in a fragmentary manner, to aspects related to the socio-economic status, personal hygiene and sanitation.
4. As shown in the analytical framework (See Figure 5.2) I am expecting to encounter several instances of inter-relations between levels, such as between the environment and socio-economic or behavioral aspects. For example, I am expecting that:
 - Sanitation facilities and their usage inside the household be, to a certain extent, determined by the quality and reliability of provision at neighborhood level
 - Interactions with neighbors influence mothers' and carers' choices when it comes to hygiene and anti-mosquito measures for their children. Thus, I am expecting that the mothers/carers who have stronger ties with their neighbors and who discuss health-related matters with their neighbors will adopt more a health-conscious conduct regarding their children.
 - The mother's/carers' lower socio-economic status and the poor household sanitary facilities have a synergistic

effect on water-related diseases. The education gradient has received a fair amount of attention in research dealing with health issues in general (D. M. Cutler and Lleras-Muney 2010; Lynch and von Hippel 2016). However, the relationship between educational attainment and environmental health, as well as the potentially protective role of education in the context of an unfavorable domestic environment, have been far less studied. Zimmerman and Woolf (Zimmerman and Woolf 2015) make the case for so-called “coping mechanisms” related to an increased level of education. However, this concerns the individuals themselves and, in the case presented by Zimmerman and Woolf, it refers mainly to mitigating the impact of stressors on health. Thus, it would be useful to investigate if/how this mechanism translates into an interaction between the mother/carer’s educational attainment and the environmental conditions in the household, when it comes to the risk of child contracting a water-related infection. Regarding this aspect, I am expecting that the mother’s education partially mitigates the potentially negative effect of unimproved sanitation infrastructures and housing amenities, whereas the lack of the mother’s education exacerbates their deleterious effect.

5. In a rapidly growing urban space such as Dakar, I am expecting to encounter aspects of sanitation which are not accurately explained by statistical indicators alone. Thus, given existing literature on sanitation in the developing world, I am expecting for indicators related to coverage to overestimate the facilities actually available for the population.

Methodologically speaking, the study uses a mixed methods approach, whereby quantitative and qualitative complement each other. Combining the two approaches in the field of population studies has been developed by proponents of anthropological demography, who argue that integrating fieldwork (by means of direct observation, interviews and photographic material) and quantitative modeling allows to better reconstruct the social and economic

living conditions of the populations studied (Bernardi 2007).

I have opted for such an approach for two reasons. Firstly, as one of the hypotheses of this study is that statistical data may not accurately depict living conditions, a complementary method is necessary, so as to identify the shortcomings of quantitative indicators. Secondly, using and triangulating two approaches in research avoids being overreliant on one method of analysis, as each method is prone to specific types of bias (Bryman 2004a). In the current study, the goal of the qualitative approach is to better understand how people really live in the areas studied, beyond the commonly used statistical indicators, thus yielding elements that would be hard (if not impossible) to observe by looking at quantitative data alone. Consequently, I have opted for a design which draws mostly from triangulation, by studying the same phenomena through two different types of lenses: the quantitative and the qualitative. However, the research also includes elements of design complementarity as it not only seeks the corroboration of hypotheses and offsetting bias, but is also aiming to gain a deeper and more comprehensive social understanding, by investigating different facets of one phenomenon (Greene 2007). Moreover, the quantitative results of the study are used to conceive the development of the other method. This, from an explanatory perspective, this allows to better explain certain results which seemed important, outliers or surprising results (Morse, 1991, cited by Creswell 2011).

Another advantage of integrating qualitative and quantitative methods is that they facilitate the study of both *if* (by means of causal statistical inferences) and *how* (by means of more in-depth discussions) behaviors and environment interact and impact on child infectious diseases. As a result, this mixed methods approach allows to better grasp the multidimensional character of the topic and to mitigate for the potential deficiencies in data available to measure it.

Regarding the choice of methods, in order to respect the hierarchical conceptualization and at the same time allow for a more comprehensive picture of the phenomenon, the study employs a multilevel modelization, with some of the explanatory variables constructed

by means of latent class analysis (LCA)¹. This approach, which is more used in research from areas related to educational studies and psychology and less in health-oriented studies, has the added value of allowing the inclusion of a relatively large set of indicators, but grouping them into synthetic categorical variables to be used in the explanatory model (Landale et al. 2013; Porcu and Giambona 2017).

In conclusion, the present research broadens the sphere of interest regarding water-related diseases to older children and intraurban inequalities and to their impact on health. It integrates components at both the lower (the individual) and the upper (the area) levels, while opting for a more parsimonious statistical modelization. Finally, it takes advantage of several types and sources of data, combining a quantitative and a qualitative approach, in order to palliate the possible biases induced by deficient statistical indicators and to get a more comprehensive view of the web of determinants for water-related diseases in children living in an urban Sub-Saharan context.

¹See Chapter 6

Part III

DATA AND METHODS

This research has a twofold goal: on the one hand, it aims to circumscribe the network of factors favoring water-related infections in children, at the individual, household and neighborhood levels. On the other hand, it also aims to provide an in-depth understanding the interdependencies and specific mechanisms of action of these factors, as well as the perceptions of families about their immediate environment and their strategies to face health-related challenges. As already stated, it is primarily for this reason that I have opted for a mixed methods approach, using – where possible – triangulation of the quantitative and qualitative data on topics related to behavior and environment. Hence, several methods are used to collect data on the same themes, with one type partially compensating for the shortcomings of the other type (Denzin, 1978, cited by Bryman 2004b; Jick 1979). Where triangulation was not possible, I have opted for an approach of complementarity, by capturing different dimensions of the same phenomenon and thus aiming to achieve a more complex understanding of the concepts studied (Greene 2007). Additionally, some some topics of particular interest were dealt with a development/explanatory design approach in mind, so that the construction of the qualitative instrument built upon the initial quantitative results (Creswell 2011; Greene 2007; Robert Burke Johnson and Christensen 2014).

The mechanism I adopted in doing so was to start off using quantitative analysis and, subsequently, selecting certain observations – here, neighborhoods – on the basis of characteristics highlighted in the statistical modelling. These observations were subsequently chosen for further, more in-depth study using qualitative methods (Morgan, 1998, cited by Bryman 2004a). Thus, the qualitative analysis – interviews and photographic material – provide analytic texture and allow for interpreting the results derived from large-sample data (Miles et al. 2012; Small 2011). Consequently, the research follows a general deductive and quantitatively-driven sequential design, with most of the quantitative analyses done first, followed by the qualitative ones (Schoonenboom and R. B. Johnson 2017). This being said, there was a certain amount of returning to the statistical models after the qualitative analysis, for further investigation².

²For example, for mosquito nets (See Chapter 11)

From an epistemological point of view, the research is done in a pragmatist manner, where assertions are based on directed inquiry – rather than on presuppositions about the world – which naturally leads to multiple methodological perspectives (Scott and Briggs, 2009 cited by Small 2011). This approach has several points in common with the grounded theory approach, as promoted by Strauss, which aims to generate principles regarding a certain phenomenon in an inductive manner, by systematic collection and analysis of the data pertaining to it (Strauss and Corbin 1991). The similarities between pragmatism and grounded theory have lead some authors to question the contributions and added value of the grounded theory approach, in the context of pragmatist qualitative research (Bryant 2009). However, such epistemological debates are largely beyond the scope of the current research, which aims to establish a reciprocal relationship between theory and analysis, be this perspective considered as pragmatism or as grounded theory. Therefore, I will use the term “pragmatism” throughout this study, to refer to the approach of adapting the philosophical and methodological approach to the specificities of the phenomenon to be studied.

Chapter 6

Quantitative Analysis

6.1 Data: The ACTU-PALU Project

This chapter deals with the statistical data available, given the objectives of the current research, as well as with the methods chosen to analyze this data.

Interactions between determinants which may be situated at different levels of analysis represent one of the main points of interest of this study.

There are, first of all, the interactions between socio-economic status and environment. The analysis is based on the hypothesis that environmental risks will affect less the children from more educated or more wealthy families, because these families know (and can afford) to prevent disease and counteract these environmental risks.

Second of all, there is the possible association between the use of mosquito protection measures and the presence of mosquitoes. It is likely that the use of these measures strongly depends on the nuisance of mosquitoes inside the compound, which is – in turn – a function of the vector density in the neighborhood. In this case, the use of protective measures would be unequally distributed in the whole population and neglecting this association could lead to biased results concerning the effect of mosquito protective measures on vector-borne febrile diseases.

Third of all, there is the aspect of possible co-morbidity (and of the factors favoring it) between the two affections studied: fevers and diarrheas. The thesis seeks to identify possible interactions between the two symptoms, in terms of the environmental factors which influence co-morbidity and those which are unique to each pathology.

To address these interactions between factors situated at different levels, a multilevel approach is essential, since classical approaches ignore contextual effects and, consequently, these between-level interactions. A multilevel approach on the other hand allows for modelling contextuality and, hence, also the relationship between micro and macro levels: child, family and household, neighborhood.

To this purpose, the thesis uses the hierarchical quantitative data of the project “Paludisme et diversité de l’environnement urbain africain : un enjeu majeur pour la mise en place des thérapies à base d’artémisinine” (ACTU-PALU).

The project was elaborated in light of the extension of chemoresistance of the *Pl. falciparum* to chloroquine and the wide-scale introduction of new artemisinin-based therapies. It was conducted between January 2008 and July 2011 in 50 districts of Dakar and its suburbs, was coordinated by the Institut de Recherche Pour le Développement (IRD) in France, in collaboration with the Cheikh Anta Diop University of Dakar (Lalou 2012). Altogether, five institutions from France and Senegal participated in the elaboration and implementation of the project, which covered the four subdivisions of the Dakar district, *i.e.* Dakar city, Guédiawaye, Pikine and Rufisque.

The main objectives of the project were to identify environmental and behavioral risk factors particular to life in the city, as well as to offer an in-depth perspective into the driving forces of using anti-malarial treatment. Thus, it aimed to help improve the effectiveness of new strategies of therapeutic fight against malaria in urban areas, where health-seeking meets medical, social, economic and environmental forces.

The survey was divided into three sections:

- a biological section (dealing with the exposure to *Anopheles*

mosquito bites and to the prevalence of malaria)

- a socio-behavioral section (referring to the access to and usage of healthcare, as well as the abundance of antimalarial treatments for children)
- a public health section (dealing with the adherence of the medical personnel to the new antimalarial strategy)

The first two components were carried out jointly on a sample, whereas the third component was conducted in 5 healthcare establishments in Dakar.

This thesis uses data from the socio-behavioral section of the project, which consists of two surveys, carried out at a timespan of approximately 6-10 months of each other.

The first survey was done by means of questionnaires, on a sample of 2952 households (living in 50 neighborhoods of Dakar), which include over 7300 children. The survey took place during and just after the rainy season (from the 15th of September to the 22nd of December) 2008, and covered aspects related to socio-demographic characteristics, behavior, characteristics of the dwelling and area of residence, as well as the occurrence of an episode of diarrhea or fever in children from the household. It was designed having a nested structure of the data in mind: children (individuals) living in families (households) located in certain areas (neighborhoods). Data collection was organized in seven stages:

1. Obtention of the research authorization
2. Awareness campaign
3. Field organization and staff training
4. Data Collection
5. Centralization of results
6. Data cleaning
7. Statistical analyses

The second survey took place during the months of July and August 2009, in the same 50 neighborhoods where the previous survey had been conducted, and was developed as a community survey.

Sampling Design

The survey sample was constructed via a two-stage stratified sampling process.

First Stage

The 2002 census data, provided by the Agence sénégalaise de la Statistique et de la Démographie, was used as sampling frame for the survey. The socio-demographic and economic data from the census counted 1 983 093 inhabitants and 270 669 households, located in Dakar's four subdivisions (Dakar City, Guediawaye, Pikine and Rufisque) and their 42 districts. It allowed for the mapping of Dakar's approximately 2000 EAs, each comprised of – on average – 86 concessions¹, 141 households and 1037 inhabitants (Lalou 2012). All EAs were geo-referenced, in order to create a Geographic information system (GIS) database.

Subsequently, dimension reduction was performed on census variables, in order to establish the dimensions which best summed up the information for the group of census variables. The dimensions thus brought out, were then used for clustering EAs, using the k-means method².

This allowed for five types of EAs to be distinguished (See Figure 6.1). The first three (Type 1, Type 2 and Type 3) were mostly to be found in Dakar city, whereas the last two were primarily found in Pikine (Type 4) and the extension of Pikine (Type 5). The 307 EAs belonging to Type 1 consisted primarily of households with a good socio-economic condition, whereas the 274 EAs of Type 2 and 335 EAs of Type 3, of respectively average and low situation. Both Type 4 (528 EAs) and Type 5 (526 EAs) – found above all in Pikine and its extension – consisted primarily of low-income households.

This clustering was then used in a spatial representation at the district level. Thus, for each of the 42 districts in the Dakar area, the dominant type of EA (among the 5 types previously distinguished)

¹In Sub-Saharan Africa, a “concession” refers to a plot of land, usually enclosed, with one or more dwellings and households

²K-means clustering aims to partition n observations into k clusters in which every observation belongs to the cluster with the nearest mean

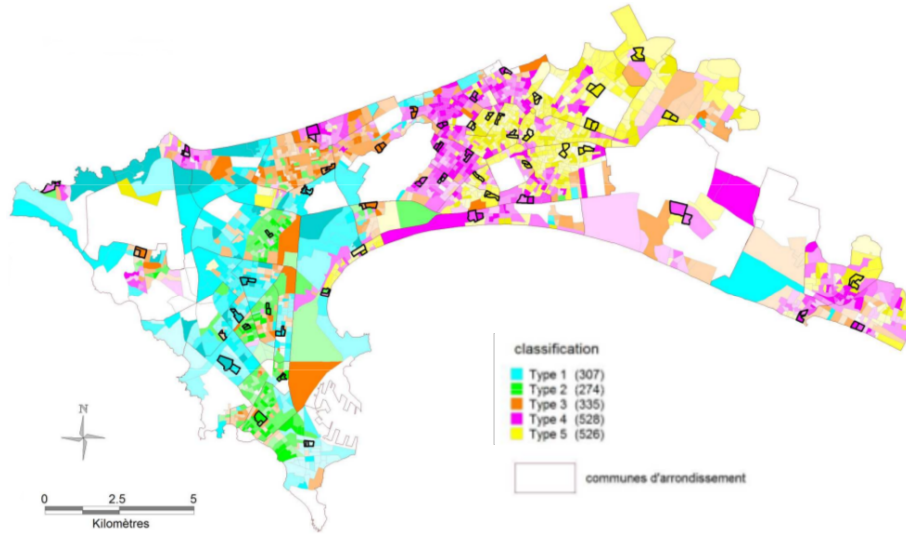


Figure 6.1: The 5 Types of EAs

Source: Lalou 2012

was identified. Then, the EA which was most representative of the dominant type, was selected in each district. In this way, 42 EAs (belonging to different districts) were selected in the final sample (Lalou 2008).

However, since the study had planned 50 EAs to be surveyed, 8 more clusters needed to be identified. These 8 supplementary EAs were chosen purposively, based on their location (near a lowland or a mudflat) and their social characteristics.

Finally, to each of the 50 EAs chosen, a pair was added (therefore 50 more clusters were added to the sample), in order to have a sufficiently large supply of potential households to survey (and in two instances, a third EA was added to the pair, in order to obtain a sampling interval / skip of $\frac{1}{3}$). These 50 additional EAs were chosen based on the following criteria:

- being adjacent to the EA chosen initially
- belonging to the same main type as the EA chosen initially
- belonging to the same neighborhood as the EA chosen initially

A total of 102 EAs were selected (50 initial EAs, 50 pairs and 2

additional EAs). The total population of these 102 EAs was 106 251 (meaning an average of 1042 individuals):

Table 6.1: Comparison between EAs

	Inhabitants (Average)	Households (Average)	Concessions (Average)
Initial EAs	2 046 171 (1037)	277 844 (141)	169 278 (86)
Selected EAs	106 251 (1042)	13 915 (136)	8760 (86)

Altogether, 50 neighborhoods (or their EA equivalent) were selected from the Dakar metropolitan area. An average of 60 households per neighborhood, meaning a total of 3000 households was set as target for the second stage.

Second Stage

Given that an updated sampling frame was not available at the primary sampling unit level, the population to be surveyed could not be sampled via random sampling. The choice of the concession, dwelling and household surveyed was assigned to the pollster (Lalou 2008). The itinerary method was chosen at the concession level, with a starting point chosen at random on an aerial photo.

For concessions with several households, the team first contacted the “chef de concession”, in order to establish the connection with the eligible households. At this level, the response was 96%. This means that, out of all the concessions selected, in 4%, the survey team was not allowed access to any of the households inside. In these cases, the team moved on to the following concession to be sampled and repeated the procedure.

Once inside the concession, the team proceeded to select the households to be surveyed. In order to be eligible, a household needed to include at least one child between 2 and 10 years old (Lalou 2008). At the household level, another 2% of refusals were recorded, where the head of the household contacted refused to participate in the survey. There was no case where, once the head of household agreed

to the survey, any one member of the household refused to take part (Lalou 2008).

Given that the survey team was instructed for each refusal to be replaced within the same EA, a final 98.4% response rate was achieved in the end, counting for 2952 of the 3000 households (Lalou 2008).

In each household, two questionnaires ³ were administered: the household questionnaire and the “woman questionnaire”, administered to one of the women in the household, who had at least one child aged 2 to 10 (Lalou 2008).

Survey Content and Structure

The general aims of the survey were to:

1. Define the socio-economic, environmental and health profile of the surveyed populations and neighborhoods.
2. Isolate information on therapeutic practices, both in contacting healthcare establishments and with regard to self-medication
3. Collect data on the constraints, perceptions and representations which determine contacting a healthcare establishment in case of a disease episode
4. Analyze the degree of patient adherence to the system of biomedical care, in particular with regard to child malarial treatments
5. Define and explain the perceptions of this medication
6. Understand why, how and to what extent patients do not comply with their treatment

For this, the survey was divided into three questionnaires, following a hierarchical structure: the individual, the household and the neighborhood (See Appendix B). The household questionnaire was, in the vast majority of cases, addressed to the head of the household (and in relatively few other cases to the household head's

³The questionnaires were tested during the pilot survey, which took place between 15 and 24 April 2008

spouse). It consisted of 6 sections and dealt with the members' socio-demographic characteristics, dwelling characteristics and wealth.

In each household, a second questionnaire was administered, to one of the women in the dwelling who had at least one child of less than ten years old. This "woman questionnaire" was constituted of 11 sections and tackled aspects related to cultural and socio-demographic characteristics, occupation, the perception of the neighborhood, social networks, health-related attitudes and behaviors and knowledge with regard to malaria.

Finally, 6 to 10 months after the initial round, a second round was organized in the 50 neighborhoods selected. Here, guided interaction between the pollster team and a group of key informants was recorded and the answers were coded into a neighborhood questionnaire. This questionnaire consisted of 8 sections, dealing with the history of the neighborhood, its physical characteristics, infrastructure and sanitary facilities, transportation, its associations and the targeted health-related interventions implemented in recent years.

The Household Questionnaire

The household questionnaire, administered in most cases to the head of household or to their spouse, was divided into six modules:

H1 Characteristics of the household members

H2 Features of the dwelling

H3 Amenities

H4 Household durable/hard goods

H5 Monetary resources

H6 Household expenditures

Module H1 also documented, for all children aged 2 to 10 in the household ⁴ the occurrence of:

⁴The survey did not include children younger than two, in order to avoid possible bias due to breastfeeding

- an episode of diarrhea in the previous 15 days
- an episode of fever in the previous 30 days, from which the child had recovered at least 3 days prior to the survey, so as to have a clear image of all potentially linked symptoms. It excluded fevers occurring simultaneously with toothaches, wounds, spots or ear aches ⁵

The Individual Questionnaire

The individual questionnaire, administered to one of the women in the household who had a child aged 2 to 10 at the moment of the survey, was comprised of eleven modules:

F1 Socio-demographic and cultural traits

F2 Activity

F3 Mobility

F4 Perception of the neighborhood

F5 Movement within the city

F6 Social networks

F7 Psychosocial aspects of health

F8 Knowledge and attitudes regarding health, malaria and medication

F9 Perception of sanitary infrastructures in the neighborhood

F10 Healthcare-seeking during the last febrile episode of the child

F11 Family pharmacy

The F10 module dealt with the handling of the child's last episode of fever. It covers both seeking aid in a healthcare establishment and the use of medication.

The Community Questionnaire

The community questionnaire was conducted in the 50 neighborhoods selected in the survey. The pollster team returned to these 50

⁵The aim of excluding these causes/symptoms was to try to circumscribe these febrile episodes to vector-borne infections

neighborhoods during the months of July and August 2009. This second passage aimed to collect mostly quantitative (and some qualitative) data on the neighborhood and its population, particularly with regard to the socio-economic and cultural characteristics. It gathered data on the collective resources and infrastructures of the neighborhood, on the environment and on the history of settlement in the area:

- N1 Characteristics of the sources / participants
- N2 History of the settlement in the area
- N3 Physical Environment
- N4 Community facilities and infrastructures
- N5 Health and social facilities
- N6 Accessibility and transports
- N7 Neighborhood groups and associations
- N8 Awareness-raising campaigns

The questionnaire was implemented before and at the beginning of the yearly high malarial transmission period (July - August) in 2009, which is the rainy season and often causes major flooding in Dakar. The community questionnaire followed the method of group interviews with key informants (sources) of each neighborhood. Thus, for every question asked, the participants were encouraged to express their opinion and eventually come to a consensus with regard to the final answer. Since the interactions between participants were recorded, this yielded supplementary information on the topics discussed. Therefore, the community questionnaires generated two types of information

- quantitative information, via the common answer to each question, after consensus was reached
- qualitative information, via the discussions generated by each question

In this context, although both types of information from the community questionnaire will be used in this study, it is primarily the quantitative data which will constitute the basis of the analysis.

However, auxiliary qualitative information from the recordings will also be used, where additional material is necessary to confirm or explain results obtained in the statistical analyses.

Data Structure

The hierarchical structure of the data thus collected, allows for a multilevel statistical approach, which takes into account the non-independence of individuals within the same cluster (children from the same household, households from the same neighborhood) and permits to distinguish the effect of neighborhood or household-related variables from that of micro level ones.

6.2 Methods and Techniques

6.2.1 Statistical Analysis of Nested Data

Hierarchical Data

Using data that has a hierarchical (or multilevel or clustered) structure is becoming increasingly commonplace in social science research. However, having observations grouped into clusters introduces a certain amount of association among the observations of the same cluster. This is because in a clustered sample, selecting two individuals from the same group adds less new information than would a completely independent selection (Shackman 2001). This form of statistical dependence usually needs to be accounted for, as it means that the sample size does not correctly reflect the quantity of information in the data, especially when there are many observations per group (Moen et al. 2016).

Traditional models do not do that and therefore, the standard errors of regression coefficients are wrongly estimated, which yields erroneous confidence intervals for the coefficients of covariates at both the lower and higher levels. Random effects models mitigate for this aspect, as they consider these clusters as being a random sample from a population of clusters (Li et al. 2011). This means that, on the one hand, standard errors are more robust, by allowing the estimation of variance in the response variable both within and between groups. On the other hand, since it considers the groups studied to be just a sample of all possible groups, allows to

interpret findings not only for the subjects/groups included in the sample (Moen et al. 2016).

In the case of the current research, the statistical analysis rests on three levels: the individual (which refers to the child or to the child's mother/carer), the household (the family and the dwelling) and the neighborhood (the area in the immediate vicinity of where the child's dwelling is located). Thus, the general three-level model becomes:

$$\text{logit}(y_{ijk}) = \beta_0 + v_k + u_{jk} + e_{ijk} \quad (6.1)$$

where $\text{logit}(y_{ijk})$ is the outcome of the symptom considered (diarrhea or fever) for child i living in household j located in neighborhood k , β_0 is the average proportion across all households and neighborhoods (the "grand mean"), v_k is the effect of the neighborhood, u_{jk} that of the household and e_{ijk} is the residual error term (Leckie 2013; Steele 2013). Since I have opted for a logit link function, the outcome is measured as $\log\left(\frac{p}{1-p}\right)$, so the log of the odds of the occurrence of an episode of diarrhea/fever.

I have added random intercepts at the household and neighborhood levels, because both households and neighborhoods sampled represent only a part of the total population of households and neighborhoods of Dakar. This implies that predicting the values of the outcome variable for groups not included in the sample does not depend solely on the covariates included in the model, but also on the "baseline" of each group (be it household or neighborhood).

Multilevel Logistic Regressions

The utility of adopting a multilevel approach, by including random effects in statistical models, depends on the amount of bias introduced by the fact that observations are clustered. This is generally referred to as the design effect (D_{eff}).

For estimating this D_{eff} , several criteria have been proposed. They are useful primarily because including random effects in a model implies an association structure in the data, and these criteria allow to quantify it. The first one is the intraclass correlation (ICC).

It represents how strongly units in the same group resemble each other, relative to two units chosen completely at random in the population (United Nations Department of Economic and Social Affairs 2001). For example, an ICC value of 0.05 would mean that the units in the group are about 5 per cent more likely to have the same value than if the two units were chosen at random. ICC is calculated as the proportion of the between-group variance in the total variance (which is the sum of the between-group variance and the within-group variance).

The ICC is the most widely known measure of clustering in a sample and, in the current study, at the highest level (here, the neighborhood) is calculated as the correlation between two children i and i' within the same neighborhood k , but different households j and j' . At the household level, it becomes the correlation between two children i and i' within the same household j (and therefore also the same neighborhood k). Thus, the ICC could be seen as representing the strength of the association between children in the same household/neighborhood.

However, taking into account only the ICC may, in some cases, yield misleading results, particularly when the groups contain many elements (i.e. when the cluster size is large). In his article on the use of multilevel modeling in social sciences, Nezlek (2008) gives an illustration of such a case where, although a clear relationship exists between two variables (in part of the groups in the sample it is positive, while in the other part of the groups in the sample it is negative), the ICC is therefore zero. Nezlek argues that, in many such cases, when the calculated ICC is zero, the decision ensuing is to not use multilevel models, despite them being necessary. He argues that, due to the nature of nested samples, whenever there is a meaningful hierarchy in the data, multilevel models are preferable.

Another measure, similar in reasoning to the ICC, are the variance partition coefficients (VPCs). They report the proportion of the variation in the observed response which lies at each analysis level of the model hierarchy (Leckie 2013). Hence, the VPCs represent the percentage of variance explained by the higher levels of analysis. At the highest level (in this case, the neighborhood), in logistic models the ICC thus coincides with the VPC.

Since the VPCs rely on the same type of reasoning as the ICC, the same limitations apply to VPCs, which would imply that, taken by themselves, they do not constitute justification enough for determining the use of mixed effects models or the number of levels to be employed. This as already stated, is mainly because statistical models are used to assess relationships between measures and “even if there is no between-group variance for all of the measures of interest, it cannot be assumed that relationships between or among these measures do not vary across groups” (Nezlek 2008, p. 857).

In this context, some authors consider that a better option is to simply estimate the design effect (D_{eff}), which is in fact an adjustment used in relation to survey sample size, in the case of hierarchical data (Cunningham and R. E. Johnson 2012). By extension, it is also used to determine the impact of the clustering of the observations and to establish whether the hierarchical structure needs to be taken into account (Muthén and Satorra 1995). In effect, it expresses the loss of precision (the ratio of variances) by the use of cluster sampling, compared to simple random sampling and represents the factor by which the sampling variance for a survey is inflated over the sampling variance which would be observed if a simple random sample of the same size were used (Cunningham and R. E. Johnson 2012; United Nations Department of Economic and Social Affairs 2001). The D_{eff} is calculated as

$$D_{\text{eff}} = 1 + ICC * (n - 1) \quad (6.2)$$

where ICC is the intraclass correlation and n is the average size of the cluster. Therefore, the D_{eff} is a function of the ICC and the average cluster size and it increases either one of these parameters (Shackman 2001). A simple random sample would have a D_{eff} of 1, whereas in a clustered one, it will generally be larger than 1, expressing the loss of information due to the grouping structure of the data (United Nations Department of Economic and Social Affairs 2001). Hence, in situations with a large number of observations per group, by the sheer size of each cluster, it becomes necessary to account for this design effect, by introducing the cluster-level into the analysis (Muthén and Satorra 1995). As a rule of thumb, Satorra

and Muthén consider that a D_{eff} larger than 2, indicates that the data call for taking into account the grouping structure (Muthén and Satorra 1995).

Given the information exposed in previous pages, the current research will include all three indicators: the ICC, the VPC and the D_{eff} as measures of grouping of the quantitative data analyzed.

Multinomial Mixed Effects Logistic Regression

In the current research, one of the goals is to estimate the impact of the selected covariates (independent variables) on the odds of:

1. experiencing a diarrheal episode as opposed to not experiencing any illness
2. experiencing a febrile episode as opposed to not experiencing any illness
3. experiencing both a diarrheal and a febrile episode as opposed to not experiencing any illness

An additional development is that data operate at different aggregation levels (e.g., demographic factors operate at the individual level, dwelling amenities operate at the household level and sanitary infrastructures in the area operate at the neighborhood level) and I am also interested in predicting the impact of variables at each level on the odds of experiencing a particular type of illness episode.

The two main impediments against running a polytomous multi-level regression on a multinomial dependent variable are that, on the one hand, it would require significant computer resources, due to the potentially large number of parameters involved; and on the other hand, the scarcity of packages available for the major statistical software capable of running multilevel multinomial analyses, as well as their relative difficulties when dealing with incomplete observations.

For these reasons, as well as for general analytic simplicity, several alternatives have been formulated. The two most common are the use of either an ordinal logistic regression (in the case of ordinal data or data that can be constrained to an order) or of multiple binomial

regressions, which, when taken together, constitute a multinomial regression.

In the first case, data needs to be ordered, so that the regression can be performed. Even though in many cases, data can be 'constrained' to become ordered, there is also the aspect of the assumption of proportional odds, which is not the case in the current data.

In the second case, the procedure consists of running several 'regular' (binary) logistic regressions, one for each pair of outcomes. Hence, the data set for each model is reduced to only two outcome types and the polytomous model is parameterized a multinomial model as a series of binomial contrasts. For a dependent variable with k categories, this would imply running $k - 1$ binomial logistic regressions, because in each model, one of the categories is individually compared with the baseline category; the parameters thus estimated are combined as if estimated by the full polytomous analysis.

As Allison (Allison 1984, pp. 46-47) explains, "the likelihood function (which is maximized in maximum likelihood estimation) for the data can be factored into a separate likelihood function for each kind of event [e.g., contrasts in a multinomial model]. Moreover, those factors look exactly like likelihood functions for single kinds of events with all other events treated as censored. Thus maximum likelihood or partial likelihood estimation can be done separately for each event type".

The main advantages of using this individualized method for estimating polytomous regressions is that it is computationally more convenient and readily available on most standard software. Moreover, it is also the approach used by some statistical software, since "the individualized method is highly efficient" (Begg and Gray 1984; Pope 2014, p. 17).

In order to keep the loss of efficiency to a minimum, Begg and Gray recommend that, if the data allow a so-called "natural" category (or a more common one), it should be that category which is chosen as baseline. In case no such category exists, their recommendation is to choose the category with the highest prevalence (Begg and Gray 1984). The five categories I have considered are as follows:

- No illness (4865 children) - baseline category
- Only fever (1291 children)
- Only diarrhea (701 children)
- Both fever and diarrhea (450 children)
- NAs (109 children, for whom either one or both outcomes were not documented) - not included in the model

Since any two-category subset of a multinomial model is conditionally binomial, this constitutes a complete model with regard to diarrheal and febrile episodes in children.

6.2.2 Latent Class Analysis

One of the main advantages of the ACTU-PALU database is the large number of (potentially) explanatory variables, which cover many aspects related to living conditions, lifestyle, behavior, attitudes and knowledge about disease transmission. Hence, the survey constitutes a rich source of quantitative data with numerous potential dimensions.

A multilevel analysis requires such an important number of dimensions, because covariates need to be added at each level of analysis. However, one likely caveat of including a large set of variables pertaining to different levels is that it may lead to statistical models which are difficult to interpret or to estimate. This poor performance of statistical models with too large a number of covariates can be either due to overfitting statistical noise or to including covariates which are, to a certain extent, redundant, because they measure similar concepts. Therefore, including them all could inflate the variance/standard error of one or more of the estimated regression coefficients, which would, in turn, lead to unstable regression coefficients.

Another aspect to be taken into account is the need to employ a dataset with enough observations for each category of each covariate. However, modifying the number of observations *a posteriori* to fit the necessities of the statistical modeling is impossible, as collecting new, additional data to complete the existing one would

both prove extremely costly and difficult to achieve and would also introduce additional bias into the dataset.

Moreover, certain factors of interest in this study are multidimensional and complex notions, such as the case of surrounding environment, socio-economic status or health literacy. This means that they cannot be directly measurable *per se* and that no single indicator can express them correctly and reflect the risks they may pose to health. This type of concept can however be approximated, by clustering several relevant manifest indicators (variables which can be measured directly) and thus reducing the number of explanatory variables. The broader explanatory construct thus yielded is, in fact, the concept of interest.

One way to overcome both of these challenges – the aspect of large variable sets and the aspect of multidimensional concepts – is by firstly reducing the number of dimensions (characteristics), before proceeding to the main, “causal” statistical analyses. Since methods of dimension reduction diminish the number of covariates, this also allows to mitigate the problem of multicollinearity between explanatory variables which, albeit all pertinent and thus are important to include in the model, are associated with one another.

This dimensionality reduction, however, needs to be done in a way that is both appropriate for the theoretical framework and the type of research questions it addresses and that limits the loss of information inherent to the procedure. In order to achieve this, the thesis employs latent variables in the form of latent class analysis (LCA). The basic principle of latent variables is local / conditional independence, which postulates that the observed association between manifest variables is not due to hidden causality, but to the fact that these variables are, actually, indicators of the same underlying concept: the latent variable. This implies that, once controlled for this latent variable, the association between the manifest variables disappears, since group membership explains any relationship between the variables (statistical independence which is conditional upon the latent variable). In the case of LCA, categorical data are grouped into latent classes. One of the main advantages of using latent class analysis is that this procedure yields parsimonious models: it synthesizes a large quantity of data (manifest variables) into a pre-defined number of categories (called "classes") and sub-

sequently assigns individuals to these classes, based on their respective conditional probabilities.

On the one hand, compared to other methods of dimension reduction — such as PCA or Factor Analysis — the advantage of latent classes is that they do not assume continuous data. This means that LCA, as opposed to other methods, can be used with categorical data, without violating methodological principles of application (McCutcheon 1987). Similarly, both PCA and Factor Analysis yield continuous variables. This means that, if a categorical variable is necessary for the subsequent analyses, a second, clustering step is needed. With LCA, both of these manipulations can be achieved in only one step.

Moreover, while both PCA and its implementation for categorical variables, MCA, use geometrical (orthogonal) transformation (based on location), LCA uses probabilities. Within each latent class, the observed variables are assumed to be statistically independent. This implies that the initial association between the observed variables is explained by the membership of the observations to one or another class of the latent variable (McCutcheon 1987). This aspect — together with the fact that the number of classes is determined by the researcher, based on the scientific literature or exploratory data — yields results that are more intuitive and easier to interpret.

On the other hand, compared to tree-fitting models for classification, such as Classification and Regression Trees (CART) and random forest analyses, the advantage of LCA in this case is that it is better suited for research based on an *a priori* analytical framework and theoretical approach, whereas decisional trees are better suited for exploratory data analyses (Pearson 2018). Moreover, each tree-based method also has specific limitations, with CART methods being associated with estimates (predicted classes and probabilities) that are sometimes unstable and random forests, being an aggregate over several trees, does not produce one single tree diagram, which is the goal here (Hayes et al. 2015).

In LCA, the procedure of class estimation aims to maximize the likelihood criterion (Linzer and Lewis 2011b) and is therefore done in an iterative manner, so as to avoid local maxima (Vermunt and

Magidson 2003). The final model calculates two sets of parameters (probabilities): the first set are the probabilities of latent class membership (whose sum is 1, since each individual will eventually be assigned to one class and one class only); the second set are the conditional probabilities, those of having a certain value on each of the manifest variables, given the latent class membership (Landale et al. 2013).

For example, in a model with 3 manifest variables — A , B and C — with respectively i , j and k modalities, let X be the latent variable estimated, with t classes and let π be the expected probabilities (calculated by the model). The expected/posterior probability for each combination of answers in the manifest variables is then⁶:

$$\pi_{ijk}^{ABC} = \sum_{t=1}^T \pi_t^X * \pi_{it}^{A|X} * \pi_{jt}^{B|X} * \pi_{kt}^{C|X} \quad (6.3)$$

where π_t^X denotes the mixing proportion (the distribution of the estimated classes in the population), while $\pi_t^{A|X}$, $\pi_t^{B|X}$ and $\pi_t^{C|X}$ are the conditional probabilities which link each of the indicator/manifest variables to the latent variable. Therefore, in the population, the sum of membership probabilities for all classes is 1:

$$\sum_{t=1}^T \pi_t^X = 1 \quad (6.4)$$

Both components are necessary for interpreting the resulting latent classes. Conditional probabilities are used for analyzing the coherence of results in a latent class model, whereas, in order to use the resulting latent classes in another statistical analysis, it is the latent class membership probabilities which are used.

Since LCA is used to create models with a pre-defined number of classes, the researcher is able to make this choice, in order to

⁶To be noted that the true value of π_{ijk}^{ABC} in the sample is known, because it represents the proportion of observations with the combination i, j, k on variables A, B, C . The algorithm thus aims to estimate this value as close as possible, while introducing the latent classes of X

best fit the theoretical approach adopted. This exploratory step involves an inductive reasoning, as several models, each with a given number of classes, are possible for the same data. In this context, the researcher is the one who chooses, based on theoretical and statistical criteria, the one(s) which are most appropriate for the research goals.

However, in practice, the number of classes which can be estimated in a model is limited, and this for several reasons. First of all, models with many classes – especially if the manifest variables also contain several modalities (i.e. are not dichotomous) – tend to be quite difficult to interpret. This, in turn, makes it difficult to establish hierarchies between classes (such as would be necessary with regard to socio-economic status, for example). Second of all, past four classes, the model tends to become difficult to estimate, which makes for lengthy iteration processes, with an increased risk of not finding the global maximum log-likelihood (Linzer and Lewis 2011b). Third of all, while adding an additional class will increase the fit of the model, it increases the risk of fitting to noise, all the while estimating extra model parameters at the expense of residual degrees of freedom (McCutcheon 1987). Therefore, among several models with similar explanatory capacities, a general principle would be to use the model with the least number of classes.

For comparing the fit of multiple models from a purely statistical point of view, the 2 most widely used indicators based on the log-likelihood function are the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). The two criteria use fundamentally the same model-selection formula, but assigning different constants across the models (Sclove 1987). The AIC allows for two variables in the model-selection formula. Thus, for each model, it becomes:

$$AIC = -2 * \ln(\max(L)) + 2 * m \quad (6.5)$$

where $\max(L)$ is the maximum of the likelihood over the parameters in the model and m is the number of independent parameters in the respective model. The BIC employs the two aforementioned variables, but also includes the number of observations:

$$BIC = -2 * \ln(\max(L)) + \ln(n) * m \quad (6.6)$$

where n is the total number of observations. Since the BIC favors models with fewer parameters than the AIC, it is generally considered to be more appropriate to latent class models (Linzer and Lewis 2011b; Sclove 1987). However, as a general rule, between several models, the choice is for one that minimizes the BIC and/or AIC value.

In this context, after taking into consideration the available data, the choice of the variables included, number of classes and model for each estimated latent variable consisted of three steps:

1. theoretical considerations
2. statistical fit
3. parsimony considerations

Consequently, the first criterion for selection between several models was the available scientific literature on the subject, regarding relevant indicators and the suited number of categories. When several models proved to be of similar interest, a subsequent analysis of their AIC and BIC values was performed. Finally, between several models with similar fit, the one with the fewest number of classes was chosen.

In this manner, five latent variables were estimated using the poLCA package in R (Linzer and Lewis 2011a; R Core Team 2013). Of these, three concern the household level and two, the neighborhood level⁷. The latent variable estimating household wealth comprises three classes and was constructed using asset ownership indicators (Filmer and Pritchett 2001). Also at the household level, health literacy was estimated by a two-class latent variable, based on knowledge and behavior regarding disease and medicines, while the dwelling's amenities were estimated by a two-class latent variable, based on sanitary facilities and construction materials. At the neighborhood level, two latent variables estimate the coverage and perceived quality of infrastructures related to

⁷For more detailed information on the indicators used in estimating latent variables, see Chapter 6.3

sanitation (drinking water, wastewater and solid waste collection), both of which are based on two-class models.

Within the chosen model, the individuals are assigned to latent classes, according to their calculated membership probabilities. These latent classes therefore become categories of a new variable in the database and hence, they can be used in other types of statistical analysis. In this case, they were included as explanatory part in a multilevel logistic regression, to analyze their impact on the two dependent variables of interest: the occurrence of a febrile or a diarrheal episode in children.

6.3 Concepts and Measures

The pages to follow examine the indicators used for the quantitative analysis of this study. On the one hand, the variables which the statistical models aim to explain: whether or not the child suffered the symptoms of a water-related infection. On the other hand, the variables which were, either in themselves or by means of constructing latent concepts, used as explanatory parts in the aforementioned models.

6.3.1 Explained Variables

The ACTU-PALU project documented the occurrence of a recent episode of fever (in the thirty days preceding the survey) or diarrhea (in the fifteen days preceding the survey) for each child of the household. Both the incidence of a febrile and of a diarrheal episode were declared by the household interviewee, which in the vast majority of cases was either the head of the household or one of his wives. For febrile episodes, the interviewers asked the respondent whether the episode in question coincided with mumps, cuts, skin rashes or toothaches and, in case of the affirmative, excluded these episodes from the febrile episodes of interest.

6.3.2 Explanatory Variables

The explanatory part of the quantitative analyses in this study consists of two types of concepts. On the one hand, most variables

employed are present in the ACTU-PALU dataset itself and have been collected during the study. On the other hand, there are the five latent variables which I constructed, based on other variables, manifest ones from the same dataset. These latent variables estimate concepts of interest for this research, to then assess their role in childhood water-related diseases. In other words, the five latent variables express concepts whose impact on water-related diseases I was aiming to measure. Hence, the latent variables refer back to the analytical framework presented in Figure 5.2 from Chapter 5.

The Child and The Mother/Carer

Two demographic variables were used with regard to the child: the child's age and the child's sex. They were both provided by the household interviewee.

The breastfeeding status was not included, as all children in this sample are aged two or above and the vast majority of Senegalese women living in urban areas do not practice extended breastfeeding (Gartner et al. 2007).

Child's Age

The child's age in completed years was included as a continuous control variable, with values ranging from 2 to 10. Using the age as a categorical variable was also tested in preliminary statistical modeling, but since this did not yield different results, it was abandoned in favor of the more information-rich version of a continuous variable. Similarly, a potential non-linear effect of the child's age was also tested by including the age-square as covariate. This did not yield a distinct effect on water-related diseases and was consequently not included in the final models. The age was recorded both by asking what the child's birth date is and subsequently asking what the child's age at the moment of data collection was, in order to minimize recall bias.

Child's Sex

The child's sex was recorded alongside with the child's age and is included in the current research as a dichotomic control variable.

Mother's/Carer's Age

The primary carer's age was included as a control variable in the present study. This is because, existing literature suggests that, especially in low- and middle-income countries, maternal age can have an impact on child overall health and on infectious diseases, particularly for younger children (Finlay et al. 2011). Aside from the biological factors, social mechanisms play a major role in explaining the differentials in child health resulting from maternal age. Hence, the mother's or carer's age was included as a continuous control variable. As with the child's age, both age categories and a possible non-linear relationship, by using the squared-age of the mother/carers, were tested. However, since neither had a significant effect on either type of symptom, they were not included in the final models.

As with the child's age, the mother's/carers' age was provided by the household interviewee and was also tested as categorical variable.

Mother's/Carer's Ability to Read/Write

Maternal education is often cited among the main determinants for child health (el Samani et al. 1989; Khatab and Kandala 2011; Mosley and Chen 1984; Palloni 2006). It generally has an impact on knowledge and choices related to hygiene, preventive care and treatment in case of an illness. Therefore, since education is likely to shape health-related conduct, I have considered it important to control for the education of mothers/carers in the sample. However, since the level of education of mothers and female carers in the ACTU-PALU survey was relatively low, with almost half of women having little to no schooling at all, I have opted for a dichotomic variable which measures the ability to read and write as proxy, which is the approach adopted in several other studies dealing with populations characterized by relatively low levels of education (D. Cutler and Miller 2005; Preston and Haines 1991). However, another categorical variable, which grouped mothers'/carers' education into three categories ("none or unfinished primary", "completed primary" and "secondary or above") was also tested.

Mother's/Carer's Occupation

Having the primary carer work outside the home means that, for a potentially large part of the day, children have to be cared for by either a paid nanny or by other members of the family, by friends or by neighbours. This may have an impact on their health, as these "secondary carers" may have different attitudes and conduct with regard to hygiene and preventive care. Some studies have found that children of whom friends and neighbours take care, while their mothers work outside the home, may experience more infections than those of stay-at-home mothers (Bani et al. 2002).

The Household**Household Health Literacy**

A dichotomic latent estimates the health literacy in the household, for which I have included four indicators: two variables related to knowledge, understanding and attitudes towards medicine and two variables related to medicine purchasing practices in the household:

1. Have you ever given your child medicine that you did not know and which had been advised by someone who is not a health professional, for example an acquaintance, friend or family member?
2. In general, the instructions you are given for taking medicine when you go to the pharmacy or dispensary seem to you difficult to understand or easy to understand?
3. Do you ever buy modern medicines (except paracetamol or vitamin C) from street vendors?
4. Do you ever buy modern medicines (except paracetamol or vitamin C) from sellers at the market?

Household Wealth

In order to estimate wealth, classic approaches would use household expenses or income as indicators. However, income-based measures often face bias from under-reporting and refusals when collecting data on income (Córdova 2009). With regard to expenses, accuracy limitations have also been reported, given the lengthy questionnaires

needed to gather details regarding expenditure over varying periods of time (Howe et al. 2008). To these aspects, in developing countries, there is also that of a highly pervasive informal economy, which renders accounting for both income and expenditure difficult (Kobiané 2003).

In recent decades, another method has gained popularity: estimating wealth not by expenses or income, but by ownership of household assets. The proponents of the method implemented it by including several indicators of asset ownership and performing a PCA on them (Filmer and Pritchett 2001).

Along this line, I have chosen an approach similar to that of Cordóva (2009), who bases her method on that of Filmer and Pritchett (2001), using household long term goods (durables).

However, I will use latent class analysis (LCA), rather than ICC or MCA (Kobiané 2003). The main reason for its use is that – despite the recent popularity of ICC for estimating wealth – ICC is statistically less suitable for use with the categorical data frequently included in the creation of wealth indices. Thus, it frequently yields more modest agreement with consumption expenditure (Howe et al. 2008).

Thus, the latent variable created contained ten indicators, regarding ownership of: radio, television, landline, gas or electric cooking stove, living-room, air-conditioner, computer, refrigerator, freezer, private vehicle.

Housing Amenities

To assess the quality of household sanitary equipments and of the construction itself, a latent variable was composed, consisting of indicators on access to water, wastewater and solid waste management, as well as construction materials used for the dwelling. Aside from indicators measuring the sanitary amenities of the dwelling, I have opted to include one indicator estimating the reliability of the primary water source in the household. In much of the developing world, coverage as reflected by official statistics often tend to overevaluate access to improved water (United Nations Human Settlements Programme 2006). Often, provision is either insufficient, too expensive or unreliable. Experiencing frequent water cuts in a

household using an improved water source may lead to temporarily resorting to an unimproved one, such as street water vendors (Dagdeviren and Robertson, 2009, cited by Dos Santos, Ouédraogo, et al. 2015). Consequently, I have judged it important to add an indicator of reliability of the main water source. Thus, the latent variable on housing amenities consisted of seven indicators:

1. What is the main source of water in this household?
2. During the year, does it happen that you resort to another means of water supply in this household?
3. What type of toilet is used by the head of the household?
4. How do you usually dispose of wastewater?
5. How do you usually dispose of solid waste?
6. What is the material used for the roof of building where the head of the household resides?
7. What is the material used for the windows of the building where the head of the household resides?

Household Mosquito Protection

In the model aiming to explain the occurrence of a febrile episode, I have included a variable accounting for the methods generally used to protect against mosquito bites in the household. This variable contains the first three methods, spontaneously mentioned by the household interviewee (with prompting from the interviewer when the interviewee mentioned less than three methods, to ensure that all methods used had been mentioned), and subsequently grouped into three categories: 1) none at all, 2) (at least) mosquito nets (and potentially other methods as well), 3) only other methods, but no mosquito nets.

The Neighborhood

Since in developing countries, issues pertaining to urban health and environment often involve rather complex evaluations and need to be assessed both via statistical indicators and via individuals' perceptions, I have opted to include two latent variables which

deal with the neighborhood sanitation (an “objective” one concerning coverage and a “subjective” one concerning perceived quality). However, it is to be noted that since the neighborhood section of the ACTU-PALU project was done by means of community survey, the respondents for this section are not necessarily from the households sampled and only one, consensual, answer was recorded per neighborhood.

Aside from these, in the model aiming to explain the occurrence of a diarrheal episode, I have also included a synthetic indicator accounting for the proportion of households which consider that garbage constitutes a problem in their neighborhood. Contrary to the other variables at the neighborhood level, since this is based on a question addressed in the household survey and which was subsequently aggregated by neighborhood, the respondents to this question are members of the sampled households.

Neighborhood Sanitation Coverage

The so-called “objective” variable on neighborhood sanitary infrastructures uses three dichotomous indicators on coverage of access to water, sewage and garbage collection, which measure whether the infrastructure in question covers the entirety of the neighborhood:

1. Is there a functioning water supply network throughout the whole neighborhood?
2. Is there a (functioning) sewage system passing throughout the whole neighborhood?
3. Is there a public garbage collection service throughout the whole neighborhood?

Neighborhood Sanitation Perceived Quality

Aside from coverage, a latent variable measures the quality of these infrastructures, by means of three indicators on the opinion inhabitants have of them. Also, in order to account for possible usage of a secondary source of water by the households in the neighborhood, I have included, also at the neighborhood level, an indicator of the reliability of the water supply.

1. What do you think about the access to water in the neighborhood?
2. Are there frequent water cuts (more than once a year) in the neighborhood's supply network?
3. What do you think of the sewage (wastewater disposal) in the neighborhood?
4. What do you think of the solid waste management in the neighborhood?

Canals

In Dakar, most of the excess water accumulating during the rainy season is taken in the city's permanent and seasonal canals. This means that, for most part of the year, Dakar's canals are dry, which often makes them dub as waste disposal areas and thus puts them at risk for overflowing when the rainy season arrives (Dos Santos, Rautu, et al. 2015, See the qualitative results section of the current research). Therefore, since the presence of canals, be they seasonal or permanent, was documented in the ACTU-PALU survey, a variable accounting for it was used in the statistical models explaining the occurrence of a febrile episode.

Synthetic Indicator: Opinion about Malaria in the Neighborhood

One additional variable was included at the neighborhood level, in the models explaining the occurrence of a febrile episode. It measures the proportion of households in the neighborhood which consider that malaria constitutes a problem in their neighborhood⁸. The reason for integrating such a measure was precisely to try to, although using quantitative methods, gain some insight into whether there are additional factors at the neighborhood level which, although not measured by commonly used indicators, are perceived by the individuals/families.

Consequently, the general model presented in equation 6.1 becomes, for diarrheal and febrile episodes respectively:

⁸The respondents were presented with the statement "Malaria is a critical health problem in this neighborhood" and asked to state whether they agree or disagree with it.

$$\begin{aligned}
\text{logit}(\text{diarrhea}_{ijk}) = & \beta_{0jk} + \beta_1 C_gender_{ijk} + \beta_2 C_age_{ijk} + \\
& \beta_3 M_age_{ijk} + \beta_4 M_literacy_{ijk} + \\
& \beta_5 M_occupation_{ijk} + \beta_6 H_wealth_{jk} + \\
& \beta_7 H_health_literacy_{jk} + \\
& \beta_8 H_amenities_{jk} + \\
& \beta_9 N_sanitation_coverage_k + \\
& \beta_{10} N_sanitation_quality_k + \\
& \epsilon_{ijk}
\end{aligned} \tag{6.7}$$

and

$$\begin{aligned}
\text{logit}(\text{fever}_{ijk}) = & \beta_{0jk} + \beta_1 C_gender_{ijk} + \beta_2 C_age_{ijk} + \\
& \beta_3 M_age_{ijk} + \beta_4 M_literacy_{ijk} + \\
& \beta_5 M_occupation_{ijk} + \beta_6 H_wealth_{jk} + \\
& \beta_7 H_health_literacy_{jk} + \\
& \beta_8 H_anti_mosquito_measures_{jk} + \\
& \beta_9 H_amenities_{jk} + \\
& \beta_{10} N_sanitation_coverage_k + \\
& \beta_{11} N_sanitation_quality_k + \\
& \beta_{12} N_\%_perceived_malaria_issue_k + \\
& \epsilon_{ijk}
\end{aligned} \tag{6.8}$$

where C refers to the child, M refers to the mother/carer, H refers to the household/family and N refers to the neighborhood.

Chapter 7

Qualitative Analysis

The current study aims to offer an in-depth perspective on the network and interrelations between potential determinants of childhood water-related diseases, as well as, potentially, on the mechanisms by which these determinants (inter)act.

Generally, statistical methods offer a good starting ground for investigating such causal relationships. However, they often have a hard time understanding and describing the finer details, such as underlying reasons and motivations. In contrast, qualitative methods, which focus on people's lived experiences, offer the advantage of observing events and situations in their naturally occurring setting and thus providing local groundness to the analysis (Miles et al. 2012).

Moreover and especially in contexts where statistical data tends to be incomplete, commonly used indicators may hide significant disparities, which are easily overlooked by a purely quantitative perspective (United Nations Human Settlements Programme 2006). Therefore, I have opted for a mixed approach, using both statistical modeling as a primary method and qualitative data analysis as secondary method, in an effort to capture these finer details and disparities.

The pages to follow describe the two processes involved in the qualitative part of the research. First, I will present the two data sources I used, namely the community survey of the ACTU-PALU project

and the interviews I conducted in Dakar. For the latter, I will also lay out the steps involved in data collection. Subsequently, I will explain the process of coding and classifying the qualitative data at my disposal, namely the procedures of categorising and indexing information, in order to make sense of the data collected and to highlight its main messages and characteristics.

7.1 Data

The two sources of qualitative data used, which will be detailed in the pages to follow, are community surveys from the ACTU-PALU project on the one hand and interviews and photographic material on the other hand. Both of these sources will be discussed in the pages to follow.

7.1.1 The ACTU-PALU Community Survey

In each of the 50 neighborhoods of the ACTU-PALU survey, a discussion similar to a focus-group was organized with a handful of respondents. For each of the questions of the community survey, the ensuing talk between the respondents was recorded and when their answers converged to a consensus, the unanimously agreed-upon answer was marked and this answer was coded into a questionnaire.

As mentioned in Chapter 6 on the data sources for the quantitative analysis, these community surveys were primarily used as quantitative information. That being said, since they are also a rich reservoir of material on the perceptions of individuals about their neighborhood (by means of the discussions generated by each question), I have also used them to further investigate neighborhood infrastructures and features of the area in general.

Since the general structure of these community questionnaires has already been laid out, I will not return to it, but rather just mention that the transcriptions of the questionnaires, as a qualitative data source, were used after the statistical modelling, for two purposes. On the one hand, I used them to get additional explanations for the quantitative results. On the other hand, I used them to confirm information gathered from the semi-structured interviews.

7.1.2 Interviews and Photographic Material

The primary qualitative information source in the current study consists of fourteen semi-directive individual interviews. These interviews were conducted after the statistical modelling was completed and their main function was to explain, more in-depth, certain aspects revealed by the quantitative data analysis. Consequently, the general design of the qualitative research in this study is a relatively tight one (Miles et al. 2012). This means that the constructs studied were fairly well delineated and most of the goals were explanatory, with data selection done along the lines of the general framework for the thesis. However, since I was also interested in identifying potentially new aspects and specificities related to each neighborhood, in terms of prior instrumentation, I opted for an approach with a semi-structured guide, which allowed to both pursue prior objectives, all while leaving space for serendipitous findings.

The following pages will be detailing this “map” of the conceptual terrain studied and the aspects which I pursued in the qualitative data collection. Appendix C deals with the prior instrumentation used, in the form of the interview structure.

I did not choose the sample based on criteria of statistical representativeness, since in a qualitative approach, sampling is purposive, as opposed to random, and usually aims to gather profiles of contrasting populations (Miles et al. 2012). In this way, the cases taken into consideration cover a wide range of situations and bring new elements to the understanding of the issue in question (Dos Santos 2011).

Subsequently, photographic material was collected in each of the neighborhoods visited. This was done both during the interviewing period and afterwards, in order to best capture the issues that had been brought up by the discussions with the interviewees.

WHO?

The main objective of these interviews was not to achieve statistical representativeness, but rather to improve knowledge on the subject by emblematic cases (Dos Santos 2011). Therefore, in terms of sampling of the interviewees, my goal was to interview profiles that

were as diverse as possible. In order to better address the research questions, I adopted a purposeful sampling method, whereby participants were sought according to criteria based on the research question.

Hence, while I aimed for having a sample which included both women and men, there was a clear focus on women. This is because, as traditionally in the Senegalese society, it is women who are the primary carers of children and it is women who are generally managing the household (Buisson 2012). Since the idea was to shed some additional light on the relationship between neighborhood, habitat, childcare practices and water-related diseases, it seemed relevant to give priority to female respondents. Therefore, only two of the fourteen interviewees were male (see Appendix D).

In terms of socio-demographic characteristics, the main strategy was to find typical cases (Miles et al. 2012). The focus was hence on finding subjects which would be illustrative for a certain category of population. I was particularly interested in interviewing housewives, working mothers and nannies. This means that the information yielded by these interviews is, both due to the size and to the nature of the sample, not appropriate for making generalizations, but rather it is illustrative of other similar cases.

WHERE?

Both interviews and photographic material were collected in four neighborhoods of Dakar, chosen on the basis of statistical models, more precisely the result of residual analysis at the neighborhood level. Thus, my aim was to try and explain the particularities that these neighborhoods and why the statistical models proved less efficient in predicting their burden of water-related diseases. I have focused on only four neighborhoods of Dakar, for two considerations. Firstly, in contrast to a larger-scale approach, which would need to greatly summarize information from each neighborhood, this mode of operating “compares a small number of well-defined and purposely selected contrasting neighborhoods” (Diez Roux 2001, p. 1984). Hence, it allows for a more in-depth understanding of the exact locations which proved to be most challenging for the statistical analysis. Secondly, there were, of course, practical considerations,

which meant that in order to obtain better quality information in the chosen units, a smaller number of units needed to be selected. Thus, the chosen neighborhoods were the following:

- the two least explained neighborhoods in terms of febrile episodes
 - with a higher-than-expected prevalence: Dalifort
 - with a lower-than-expected prevalence: Unité 8
- the two least explained neighborhoods in terms of diarrheal episodes
 - with a higher-than-expected prevalence: Fith Mith
 - with a lower-than-expected prevalence: Soprim 1

Dalifort is located in the Pikine department and is bordered to the South by the ocean (being, in fact, the only neighborhood among the four selected to have access to the ocean) and to the West by the Maristes neighborhood of Dakar. Fith Mith is a landlocked neighborhood situated in the Guediawaye department, to the North-East of the Dakar department. Unité 8 and Soprim 1 are both located in the Parcelles Assainies peri-urban area of Dakar. While Unité 8 is a landlocked neighborhood located in the North-Eastern part of the city, Soprim 1, located in its vicinity, is bordered to the South by a marsh¹.

WHEN?

The qualitative data collection (interviews and photographic documentation) was done between 31 August and 11 September 2015. This meant during the second half of the rainy season, which usually leads to severe flooding after the first episodes of heavy rain. The advantage was that, in the days and weeks following the first floods, these aspects are still fresh in people's minds and therefore more accurate information is likely to be gathered.

On the other hand, this may of course lead to negatively biased opinions being expressed on topics such as sewerage, quality of drinking water and mosquito proliferation. This, in my opinion,

¹For maps of the departments mentioned and of these specific neighborhoods, see Figures 3.3 and 10.5 in Chapters 3 and 10 respectively

does not constitute a problem in itself, given that the objective of the interviews was not to create a representative image of Dakar's neighborhoods, but rather to try to provide answers to questions which had already risen from the statistical models.

All of the interviews were done in the late afternoon and early evening, so as to maximize the chance of also interviewing both mothers who work outside the home as well as stay-at-home mothers.

HOW

Since I had little prior knowledge of the specificities of the four neighborhoods to be visited and since I do not speak Wolof (one of the official Senegalese languages, which is predominant in the Dakar region), I chose to collaborate with a Senegalese sociologist, Mr. Ousseynou Sene, who had both scientific training and a good knowledge of the field, having already participated in several surveys in Dakar and being himself an inhabitant of the city. Mr. Sene is bilingual (French and Wolof) and he thus collaborated at all of the stages of data collection: the planning, the visits, the translations to and fro during the interviews and of the recordings, as well as the transcriptions.

Prior to the visits, Mr. Sene received from me the coordinates of the neighborhoods we would visit and the interview guide², which allowed him to gather some information regarding the transportation and access to the area and to become familiarized with the themes we would focus on, during the visits. Subsequently, upon my arrival in Dakar, we had two briefing meetings to further discuss the details of how the visits would be organized.

At the beginning of each interview, after both Mr. Ousseynou Sene and myself presented ourselves, the scope of the research was also briefly summarized to the interviewees, as focusing on child health and on characteristics of the neighborhood. However, the underlying hypotheses were not explained to them so as to avoid confirmation bias and socially desirable answers. The interviews were recorded, after having obtained the consent of the interviewees, who were also informed of the duration of the interview, which was

²See Appendix C

estimated between an hour and an hour and a half (see Appendix C).

Most interviews were done entirely in Wolof, with Mr. Ousseynou Sene translating my questions into Wolof for the interviewees, then translating back to me a quick summed up version of their answers, so that the interview could progress in as seamless a manner as possible. This being said, it is still possible that either some aspects were lost in translation or that interviewees did not transmit all or the same information they would have, had the interview been carried out in a common language between me and them. However, it is to be expected that these potential limitations were minimal, given Mr. Sene's professional skills as a sociologist and his rather charismatic nature.

Once all of the interviews were collected, Mr. Sene translated the recordings back into French, with a few small exceptions: some of the interviewees spoke French more or less fluently and, in expressing their thoughts, also used French words and expressions. These words were, of course, left untranslated by Mr. Sene. Also, one interview (Abdoulaye, Male, 62, Unité 8) was done entirely in French and was therefore not translated, but directly transcribed.

WHAT?

The thesis uses quantitative data from the ACTU-PALU project, which covers a wide array of concepts. Consequently, the statistical analysis includes several spheres likely to influence water-related diseases in children. To a large extent, these data provide a good overall image of the causal relationships between these spheres and the indicators of interest. However, to further investigate the two spheres which this thesis focuses on – behaviors and the environment – the qualitative data collection focused on these behavioral and environmental factors. However, as literature has shown, behaviors are often linked with socio-economic factors and interactions with others (Bender et al. 2015; Heller 1999; Onarheim et al. 2017). Hence, the interviews also investigate some aspects related to socio-economic status and cultural norms, especially regarding childrearing.

Hence, the interviews largely dealt with three main topics: the current neighborhood of the interviewee, the protective measures un-

dertaken against water-related diseases and childcare in the interviewee's household. The main research question of the qualitative component was to see why some neighborhoods were less well explained by the statistical analysis. The starting hypothesis was that these neighborhoods had specificities in their milieu, which made them different and which were not readily quantifiable; so the ensuing question was what were these characteristics, specific to the neighborhoods in question, which lead to them having a higher or lower incidence than expected. I was thus particularly interested in aspects related to infrastructure (such as quality and reliability) and landscape characteristics. Moreover, I wanted to get a more in-depth understanding of the specific situations in which people live, but also of their health-related practices and representations. Thus, the general interview structure and analysis revolved around certain aspects of particular interest:

- *Was there a connection between the (perceived) presence of mosquitoes and people's behavior in terms of protective measures?*

The quantitative analysis provided both a surprising association between mosquito protection and vector-induced febrile episodes, as well as a potential explication for it. Moreover, from some studies emerged the fact that people tend to not use mosquito protection if they do not perceive mosquito presence in their area. Thus, to further investigate the issue, I decided to delve into the topic of whether or not people used mosquito protection measures and what were their reasons for (not) doing so.

- *Concerning the three aspects of sanitary infrastructure – access to water, wastewater management and solid waste collection – were there any configurations which could affect the reliability of commonly used indicators?*

In the developing world, official statistics sometimes reflect rather poorly the quality of sanitary infrastructures, presenting an overly optimistic image (United Nations Human Settlements Programme 2006). Since quantitative indicators may fail to convey an accurate picture regarding the quality and affordability of provision, I decided to ask the people inter-

viewed about their sanitation provision.

- *Were there differences in childcare arrangements according to socio-economic background?*

The quantitative analysis yielded a positive association between having a literate mother/carer and the incidence of a febrile episode, which prompted two hypotheses to explain these results. One possibility could be the differing propensities to report disease across families of different levels of education (Filmer 2005). Since compared to diarrheal episodes, fevers are less easily noticeable by mothers, this could explain, at least in part, the counter-intuitive relationship observed. Another possibility could be related to the habit of taking a nanny for children, in families of higher socio-economic status. In order to test this second hypothesis, I looked at the interviewees' childcare arrangements.

- *What were the general practices with regard to hygiene, drinking water storage and waste storage, as well as their reasons and justifications?*

Since behavioral factors emerged as significant determinants for water-related diseases in the quantitative analysis, with a distinct impact from that of education and wealth, looking at individuals' hygiene practices and the underlying reasoning could help further explain child health differentials

- *Did people keep close contact with their neighbors, to the point where they could potentially influence each other's knowledge and behavior related to health?*

Some studies show that neighbors can have a role in health-related decision-making and practices (Nieminen et al. 2013; Onarheim et al. 2017). Thus, it was useful to see whether or not people kept close contact with their neighbors and whether they discussed aspects child health and medical issues with those living in the same area.

If the discussion lead to a shift in the order of the topics, both Mr. Sene and myself took note of the relevant details or asked additional questions, then returned to the remaining aspects that were yet to be discussed.

This being said, certain aspects, such as that of fruit and vegetable washing³ were eventually removed from the list of questions, since I noticed that most of the interviewees tended to give socially desirable answers on those particular matters.

The added value of this qualitative data is that it allows not only to investigate aspects of sanitary infrastructures which cannot be fully explained with quantitative data, but also to get a deeper insight on people's knowledge and attitudes concerning risk and protection against water-related diseases.

7.2 Analysis

Contrary to quantitative data, the qualitative one represents a more in-depth information on a small number of cases, rather than less in-depth information on a large number of cases. Its goal is different as well, in that it seeks more in-depth descriptions, rather than the measurement and quantification of specific aspects. Its collection involves constructing and reconstructing a reality which is influenced by both the interpretations of the interviewer and those of the interviewee. Therefore, the interviews and focus groups yielded material which is, at the same time, established beforehand and spontaneous, the constructed result of both analytical design and human interaction.

In this particular research, the qualitative data fulfilled a mix between explanatory and exploratory goals, in the sense that, following the quantitative analysis, several additional research questions emerged. Thus, the primary role of the qualitative data collection was to try and address these questions and test the hypotheses I had formulated regarding them. However, given the richness of the information collected, I was also envisaging potentially discovering additional relationships between constructs, as well as simply finding out what do people think about the specific aspects of child health I focused on. This means that, for the most part, the qualitative analysis was driven by statistical analysis results.

³see Appendix C

Since most coding was predetermined, but some codes were generated by the data itself, I have opted for a two-step approach in the formalization of the qualitative material. This two step analysis takes into account both the conceptualizations present in the interview structure and the additional, impromptu information yielded by the free discussions. The pages to follow describe this process of coding and classifying the qualitative data at my disposal. They trace the procedures of categorising and indexing information, in order to make sense of the data collected and to highlight its main messages and characteristics.

The first step: Thematic analysis

The first step, the thematic analysis, parses interviews according to a matrix of concepts, with the purpose of synthesizing the entire corpus of information available (Paillé and Mucchielli 2012). The main advantage of this data reduction procedure is to transform the raw data into a more useful form, by selecting only the passages which “count” for the research questions of the study (Guest et al. 2012). The matrix was largely based on the basic hypotheses of this research, albeit adapted after the initial reading of the transcripts. Thus, it combines the interview structure elaborated beforehand and the add-ons resulting from a first reading of the interviews.

This matrix is a conceptualization consisting of two main sections, the behavioral one and the environmental one. Each of them contains several themes, split into specific nodes⁴, the latter thus constituting the unit of analysis of this first step (see Figure 7.1).

The first one of the two sections referred to behavioral patterns in the household. Of particular interest here was everything that could have an impact on disease transmission. Thus, three main themes emerged, each with several nodes:

- the existence of a nanny or second carer
 - tasks performed
 - frequency/duration of caring for children

⁴A node is a virtual “container”, which holds all the content about a specific concept

- level of education attained
- hygiene
 - food hygiene (hand washing, washing of fruit and vegetables)
 - household waste storage
 - drinking water (treatment and storage)
- mosquito protection
 - reasons for (not) using a net
 - usage of nets
 - usage of other methods

The second section was related to the environment (both physical and social) of the household and of the area. Here, I was particularly interested in finding out whether and how the milieu affected the family's lifestyle and health. Consequently, I focused on:

- presence of mosquitoes
 - individual perception and mosquito nuisance
 - potential relationship with anti-mosquito measures
- neighbors
 - relationship of interviewee with their neighbors
 - practices of neighbors (household waste, mosquitoes)
- cleanliness
- landscape
 - vegetation and water
 - presence of a slope

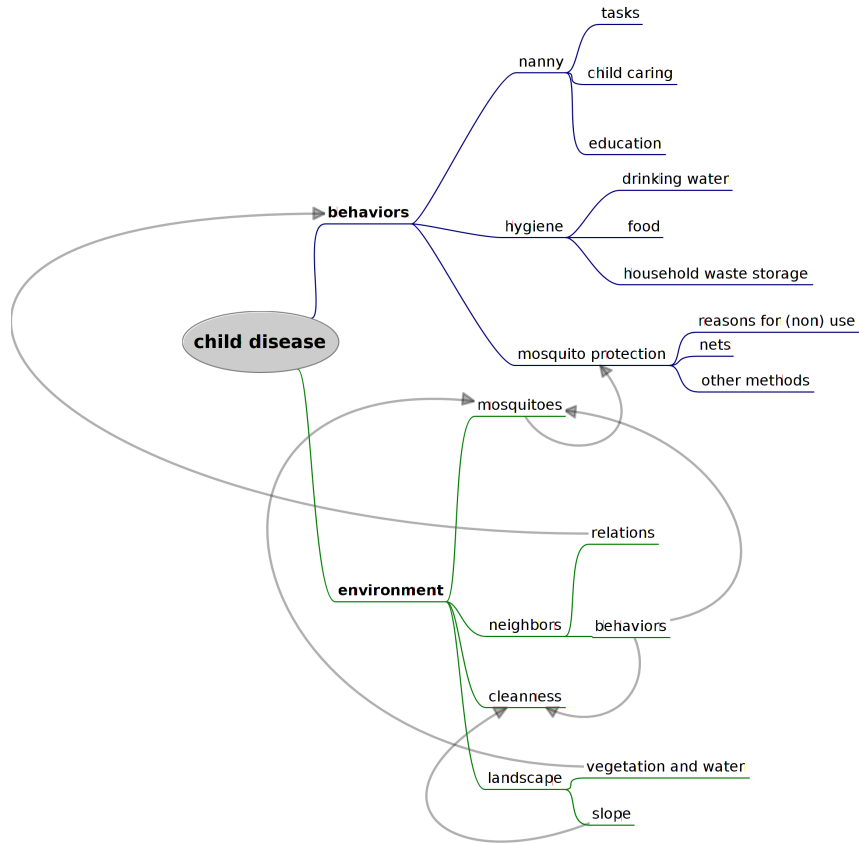


Figure 7.1: Interview Analysis Grid

As Figure 7.1 shows, after the initial reading of all of the interviews, these nodes proved to be highly interconnected, be it based on existing literature or based on discussions with the interviewees. Thus, I was particularly interested in several possible links:

1. There is some evidence in existing literature that increased levels of interaction between neighbors can sometimes have an influence, albeit not a strong one, on individual health-related behavior (Bender et al. 2015). Consequently, I was interested to know whether people were generally prone to discussing health and childcare with their neighbors. And if yes, did this influence their own way of acting and the measures they

took to safeguard their family's health?

2. Following the results of quantitative analysis, I was interested to investigate what the general reasons people gave for using or not using mosquito protection. Some studies suggested a relationship between perceived mosquito presence and protection measures (Iwashita et al. 2010; Thomson et al. 1994). Did anti-mosquito measures generally correspond to the presence of mosquitoes in the area and to the fact of being bothered by mosquitoes?
3. Given that, if people in an area generally tend to use mosquito protection, this has an impact on the density of mosquitoes in the area and also on the density of mosquitoes in dwellings where no protection is used, I was also interested in finding out if interviewees knew whether or not their neighbors protected themselves against mosquitoes in any way.
4. Since mosquitoes breed in wet areas, I was interested in the possible connection between the existence of such wet areas and the (perceived) nuisance of mosquitoes by the interviewees.
5. Heller (1999) shows that sanitation challenges faced by some inhabitants may partly be influenced by *ad hoc* waste dumping by other inhabitants in the area. Hence, I was interested in whether or not interviewee had an opinion on their neighbors' practices with regard to household waste and wastewater. Did this impact the overall level of cleanliness in the area?
6. An aspect not foreseen, but raised by several interviewees, was that of the existence of a slope in the area. In all subsequent interviews, as well as in the analysis, I was therefore interested whether or not the interviewee's house was on (or nearby) such a slope, its position on the slope and whether or not this had an impact on sanitation and general level of cleanliness in the area.

The process of labeling was done with the RQDA package in R (Huang 2018; R Core Team 2013). Firstly, each relevant piece of text was assigned to its node. This piece of information was, of

course, of very variable length and could range from short parts of sentences to several paragraphs. Once this step was completed, I double-checked, in the relevant nodes, whether connections could be established between nodes, according to the aforementioned links.

Although some studies using qualitative data resort to quantifying the nodes, there is some debate as to whether this type of approach is suitable in qualitative analyses, especially for relatively small samples, such as the case here (Guest et al. 2012). Given this relatively small sample, of fourteen interviews, I have not considered it appropriate to quantify the qualitative data or to summarize nodes by their frequencies.

The second step: Per interview analysis

After carrying out the thematic analysis, I then proceeded to a contextualizing analysis, on a per-interview basis (Paillé and Mucchielli 2012). This involved scanning each of the interviews, aiming to get a general idea of the context of the interview, the situation of the interviewee and other possibly useful clues regarding their attitudes, quality of life and the cultural norms they adhered to. The goal here was to gain access to a reality specific to each interview, and it was hence the interview in itself which constituted the unit of analysis of this second step.

Here, a piece of text did not convey meaning by being separated from the rest of the interview, but rather through the relationship with information gathered from the rest of the text regarding past events, current conditions and expectations about the future (Paillé and Mucchielli 2012). Consequently, taking the qualitative material interview by interview, I thus tried to retrace the conditions which could have contributed to specific answers for the key questions, or any supplementary aspects which were adjacent to the themes of interest. I was therefore interested in, on the one hand, any additional pieces of information which had been overlooked when looking strictly the nodes and labels used in the thematic analysis. On the other hand, I was also interested in uncovering and understanding the big picture, the context of each discussion.

This step focused more on trying to convey meaning to each interviewee and to their particular situation, to grasp the general

context of their life (dwelling, family, status) and life story and to thus put the conversation into perspective. Here, in order to get a more comprehensive image of the discussions, I looked both at the main messages of each interview and at the smaller details which may have influenced the interviewee in adopting a certain perspective.

Since this step yielded several new insights, for some interviews this meant going back and forth between the thematic and the per-interview analysis, so as to complete the picture of each of the interviews.

Summing up

After an initial reading of all of the interviews, the text of each interview was firstly analyzed in a horizontal manner, "cut out" into pieces, in order to be categorized into specific labels. Secondly, it was handled in a vertical approach, interview by interview, focusing more on the treatment of the meaning of each conversation.

This aimed, on the one hand, to achieve thematic coherence, to elaborate explanatory models of the practices described by the interviewees. On the other hand, it also aimed to achieve singular coherence, to impart a specific profile to each individual and to the discussion they had with us.

Part IV

RESULTS

Chapter 8

Descriptive Results

This chapter constitutes the results of the descriptive analysis. The first part of the chapter deals with the features of the sample¹, at the three levels of analysis:

- the 7416 children and their 4024 mothers/carers
- the 2952 households
- the 50 neighborhoods

These explanatory variables also comprised, among others, the latent variables created at the household and neighborhood levels.

As mentioned in Chapter 6, the latent class model is based on two components: a set of conditional probabilities and a mixing proportion, which represents the proportion of observations in each latent class.

On the one hand, conditional probabilities express the probability associated with each value/category of each of the indicators used, given the membership to each latent class. The sum of these conditional probabilities across all possible values/categories of a given indicator, given the membership to a specific class, is thus equal to one. Hence, these conditional probabilities allow to identify the

¹The non-responses or non-response rate are mentioned separately for each variable where the response rate was not 100%

indicators which best discriminate the data with regard to the latent variable constructed and to interpret what each latent class represents.

On the other hand, the mixing proportion expresses the probabilities of latent class membership across the whole sample, whose sum is equal to one, as each observation is eventually assigned to one and only one latent class. They allow to gauge the distribution of the classes in the population and to therefore create a synthesized representation of the sample, based on each latent variable.

Therefore, in the following pages I will present the results of both of these components for the five latent variables constructed. They refer to health-related behaviors, wealth, household and neighborhood sanitation and they allow for depicting their respective units of analysis. Subsequently, they are used as potential determinants for water-related illness.

The second part of the chapter deals with the explained variables, namely the occurrence of febrile and diarrheal episodes in the children of the sample. The two variables will be analyzed individually, as well as under the form of a synthetic morbidity variable. This synthetic variable, consisting of four categories, distinguishes between children who had both symptoms, those who had only one of the two symptoms and those who had none at all. The univariate results of the explained variables are followed by a series of bivariate (crossed with demographic and environmental characteristics) descriptive statistics.

For both the explanatory and explained parts, I will present the raw numbers/percentages in the case of univariate statistics for qualitative variables. For quantitative ones, as well as for bivariate statistics, I will also include a representation of the distribution or of the relationship in question.

8.1 The Independent Variables: Characteristics of the Sample

8.1.1 The Child and the Mother/Carer

The sample consisted of 7416 children aged 2 to 10. Of these, 3751 (51%) were girls and 3665 (49%) were boys. Over half of the children (3772) were aged between two and five at the moment of data collection (see Figure 8.1), with slightly more boys at the very young ages (between the ages of two and five) and slightly more girls at the older ages (between the ages of six and ten). As a result, the girls' sample was, on average, slightly older than the boys' one (5.7 years old for girls, compared to 5.5 years old for boys, significant at a 95% confidence interval)

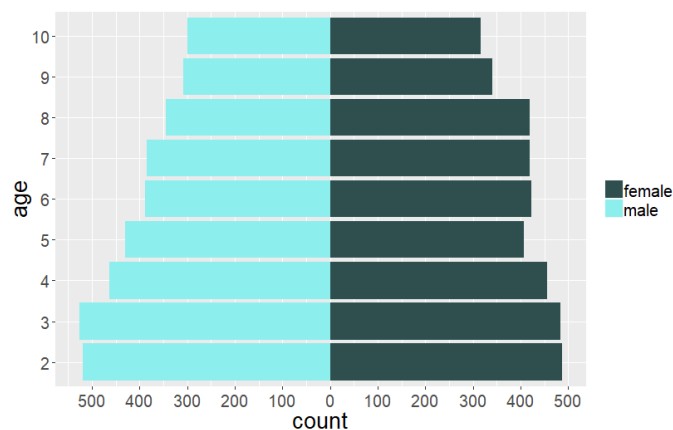


Figure 8.1: Sex and Age Distribution in the Sample

A total of 4024 mothers or female guardians of the 7416 children aged two to ten were part of the sample. Their ages ranged between fifteen and ninety years old (see Figure 8.2). Most mothers or guardians in the sample were aged between twenty-five and forty, with few of them aged fifty or older (two mothers/carers did not have their ages recorded).

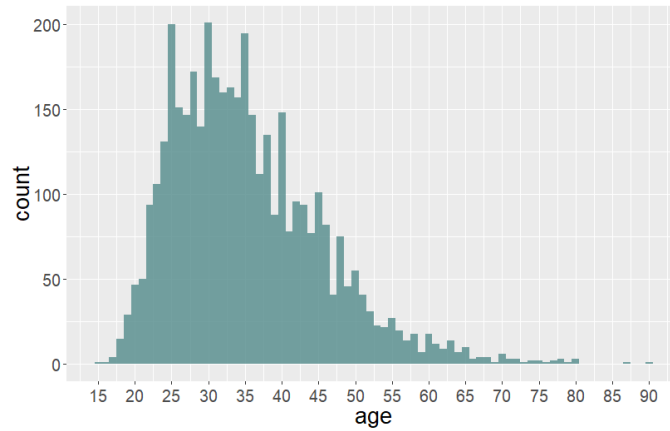


Figure 8.2: Age Distribution of Mothers/Carers

The declared literacy rate in the sample of mothers/carers was 48%, with 1944 mothers/carers being declared as able to read and write. Half (51%) of the mothers/carers were housewives at the moment of the survey, while another almost half (45%) worked outside the home. The remaining 4% had other activity statuses, such as student, trainee or doing odd jobs.

8.1.2 The Household

Concerning the 2052 households included in the sample, three latent variables were created. The first one deals with the material resources of the family and was estimated by measuring possession of durable assets. The second one deals with behaviors related to health and medicines. The third one deals with household amenities in terms of access to water and sanitation and takes into consideration access to drinking water, wastewater and solid waste management.

In terms of financial situation of the household, I have opted for a three latent class model, consistent with splitting the sample into a lower wealth category, a middle one and an upper one. The model was based on the ownership of the following long-term goods: radio, television, landline, gas or electric cooking stove, living-room, air-conditioner, computer, refrigerator, freezer, private vehicle. Table 8.1 presents the conditional probabilities associated with each of these indicators:

Table 8.1: Conditional Probabilities for the Household Wealth Latent Variable

		%	Class 1	Class 2	Class 3
Radio	No	19%	0.05	0.1	0.31
	Yes	81%	0.95	0.9	0.69
Television	No	13%	0	0.01	0.3
	Yes	87%	1	0.99	0.7
Landline	No	77%	0.22	0.68	0.99
	Yes	23%	0.78	0.32	0.01
Gas/Electric stove	No	93%	0.57	0.94	1
	Yes	7%	0.43	0.06	0
Living-room	No	56%	0.02	0.33	0.94
	Yes	44%	0.98	0.67	0.06
Air conditioner	No	97%	0.73	0.99	0.99
	Yes	3%	0.27	0.01	0.01
Computer	No	90%	0.4	0.91	1
	Yes	10%	0.6	0.09	0
Refrigerator	No	59%	0.19	0.37	0.92
	Yes	41%	0.81	0.63	0.08
Freezer	No	92%	0.6	0.93	0.99
	Yes	8%	0.4	0.07	0.01
Car	No	89%	0.44	0.89	0.98
	Yes	11%	0.56	0.11	0.02

Analyzing the conditional probabilities associated with each class (Table 8.1), it seems that the most discriminant indicators are the possession of a television, a living-room and a refrigerator, while the possession of a radio (high ownership across all classes) and air conditioning (low ownership across all classes) are less discriminant. From the analysis it also becomes obvious that the three classes appear to represent categories of wealth, with Class 1 representing higher wealth, Class 2 representing average wealth and Class 3 representing lower wealth. Thus, of the 2952 households sampled, a bit over half (1507 households) belonged to the average wealth category, while a little over 40% (1255 households) to the poorer category, with the remaining 6% (190 households) being assigned to the wealthier category (see Figure 8.3).

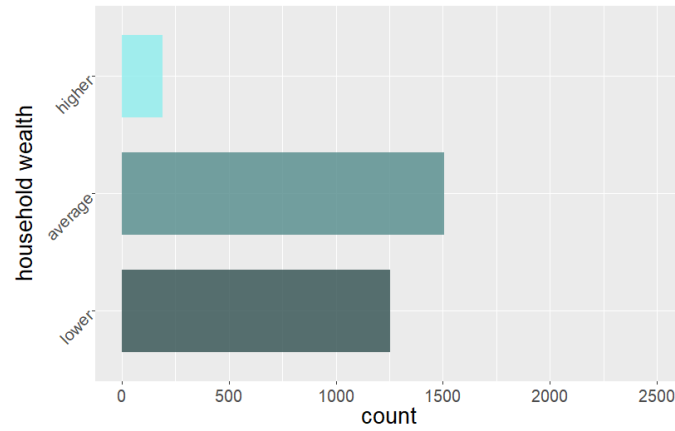


Figure 8.3: Household Wealth

With regard to the health literacy level in the household, the latent class analysis model splits the sample into two categories, based on four binary manifest variables: (1) whether or not the mother/carer interviewed in the household had given to her child medication which she didn't know beforehand and which had been recommended by someone other than a health professional; (2) whether she generally found the instructions received for taking medicine easy or difficult to understand; whether she sometimes buys modern medicine (3) from street vendors or (4) from sellers at the market.

Table 8.2: Conditional Probabilities for the Health Literacy Latent Variable

Indicator		%	Class 1	Class 2
(1)	No	70%	0.77	0.49
	Yes	30%	0.23	0.51
(2)	Difficult to understand	21%	0.2	0.25
	Easy to understand	79%	0.8	0.75
(3)	No	78%	0.97	0.16
	Yes	22%	0.03	0.84
(4)	No	81%	0.96	0.32
	Yes	19%	0.04	0.68

Looking at the conditional probabilities (Table 8.2), it seems that the two variables related to modern medicine purchasing behaviors

(purchasing from street sellers, followed by purchasing at the market) are the most discriminant, while most of the sample declares to generally find posology instructions relatively easy to understand, irrespective of latent class. Upon analyzing these conditional probabilities, I have classed the 2226 households from the first class as high literacy, and the 726 households from the second class as low health literacy (See Figure 8.4).

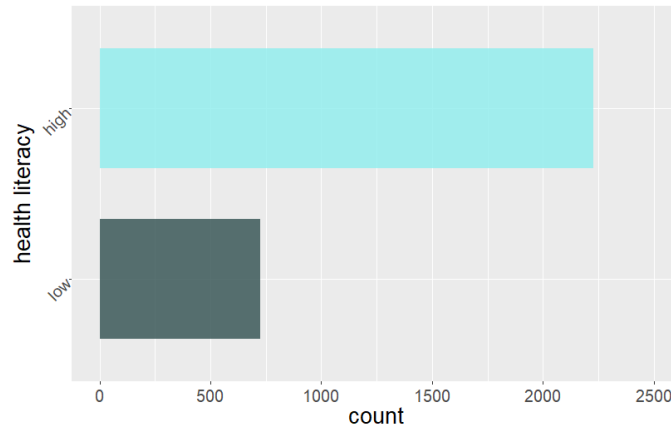


Figure 8.4: Health Literacy in the Household

The third latent variable created, referring to the quality of housing amenities, also splits the sample into two categories, based on seven indicators: whether the household had access to drinking water from a tap, whether they sometimes had to resort to a secondary water source (generally due to frequent and/or prolonged water cuts), whether they had a WC, whether they disposed of their wastewater using a sewerage system, whether they had a private bin for solid waste, whether the roof of the dwelling was cemented and whether the house had windows (glass and frame):

Table 8.3: Conditional Probabilities for the Housing Amenities Latent Variable

		%	Class 1	Class 2
Drinking water	Tap	88%	0.97	0.78
	Other	12%	0.03	0.22
Need secondary water source	No	69%	0.72	0.65
	Yes	31%	0.28	0.35
Toilet	WC	68%	0.86	0.48
	Other	32%	0.14	0.52
Wastewater	Sewer	32%	0.58	0.03
	Other	68%	0.42	0.97
Solid waste	Private bin	66%	0.69	0.63
	Other	34%	0.31	0.37
Roof	Cemented	44%	0.67	0.17
	Other	56%	0.33	0.83
Windows	Glass windowpanes	18%	0.33	0.01
	Other	82%	0.67	0.99

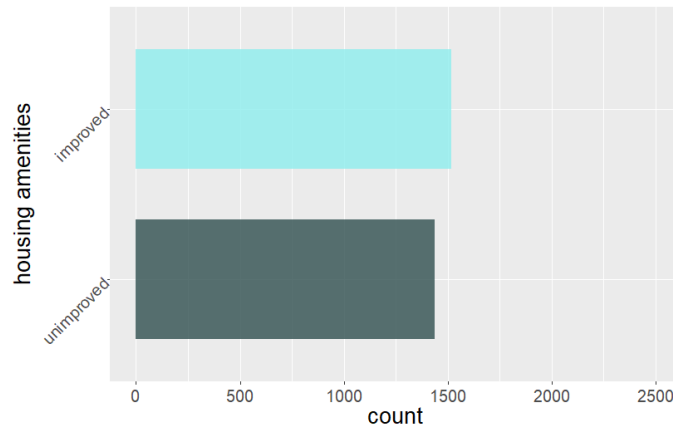


Figure 8.5: Housing Amenities

The conditional probabilities associated with the manifest variables (Table 8.3) reveal that connection to the central sewerage network and the material used for the roof were the most discriminant in the sample. At the opposite end of the spectrum, around two thirds of the sample had private garbage bins, irrespective of their assigned class. It appears that households assigned to Class 1 were more likely to benefit from improved housing amenities and had to resort less often to an extra water source, compared to those assigned to Class 2.

The latent variable split the sample into two fairly balanced groups, with 1516 (51%) households having amenities which can be considered as improved, compared to 1436 (49%) households in the unimproved category (see Figure 8.5).

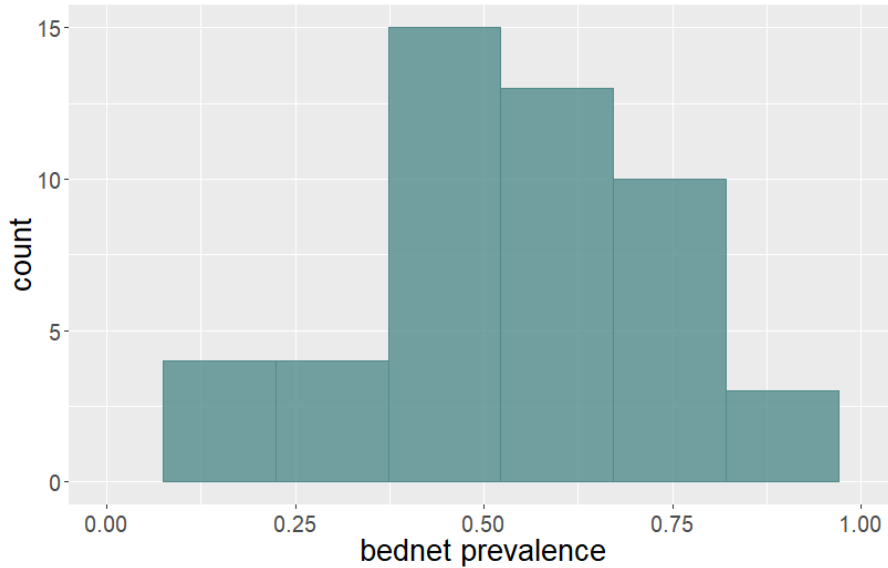


Figure 8.6: Prevalence of Bed Nets by Neighborhood

In addition to the three latent variables, for the statistical models aiming to explain the occurrence of a febrile episode, I have opted to include a variable related to anti-mosquito measures undertaken in each household. Thus, the vast majority of households in Dakar use at least one method of protection against mosquitoes: 2836 households use at least one method, of which 1567 use (at least) bed nets, while only 116 households do not use any method.

However, while on average most households (53%) use bed nets, the percentage of households using them varies significantly across neighborhoods (see Figure 8.6)

While in some neighborhoods as little as 5% of households use bed nets, in others as many as 93% do, with a distribution slightly skewed to the left, which indicates that there are relatively few households where a very low proportion of households use bed nets.

8.1.3 The Neighborhood

At the neighborhood level, the suitability of sanitary infrastructures was estimated by means of two latent variables. The first one measured the coverage of sanitary infrastructures (piped water, sewerage and solid waste collection). The conditional probabilities associated with each of the three manifest variables (Table 8.4) show that the indicator regarding piped water was the least discriminant, as in nearly all of the neighborhoods there was a piped water network, which covered the entire area (with a slightly higher probability associated with Class 2). The most discriminant was the garbage collection variable, where both classes were pure and diametrically opposite. Thus, Class 1 appears to indicate a relatively complete coverage, whereas Class 2 would indicate deficient coverage.

Table 8.4: Conditional Probabilities for the Sanitation Coverage Latent Variable

		Counts	Class 1	Class 2
Piped water	Yes	46	0.9	0.95
	Not all	4	0.1	0.05
Sewerage	Yes	15	0.45	0.1
	Not all	35	0.55	0.9
Garbage collection	Yes	29	1	0
	Not all	21	0	1

Of the 50 neighborhoods sampled, 29 had better coverage of sanitary infrastructures, while the remaining 21 had a less comprehensive network in place (See Figure 8.7).

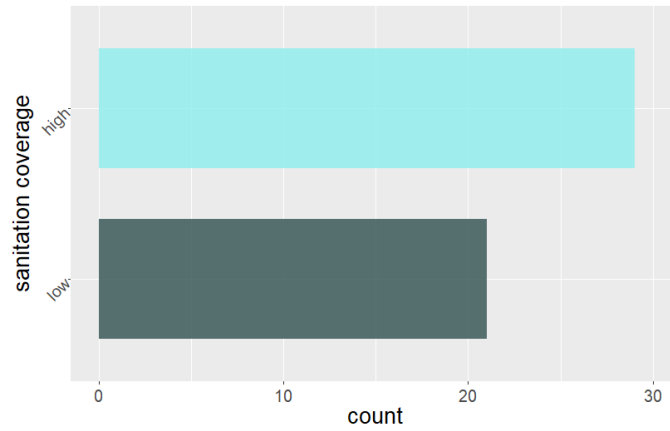


Figure 8.7: Neighborhood Coverage of Sanitary Infrastructures

The second latent variable measures the perceived quality of these sanitary infrastructures. It was constructed using four indicators, out of which three assessed satisfaction with the three aforementioned infrastructures, while the fourth one estimated whether or not the neighborhood experienced frequent water cuts.

According to the conditional probabilities linking the manifest variables with the latent one, it appears that the perceived quality of the piped water network strongly discriminates between the two classes created, followed by the quality of the sewerage system. Conversely, the least discriminant indicator, although still with relatively high dependency on class, appears to be that of frequent water cuts: neighborhoods assigned to Class 1 have slightly more than one in three (0.38) chances of experiencing frequent water cuts, compared to those assigned to Class 2, which have a little over a half (0.57). The general image created by the conditional probabilities would indicate that Class 1 expresses sanitary infrastructures of better quality, whereas Class 2 would express relatively deficient ones.

Their distribution is similar, in terms of proportions, to that of sanitary coverage, in that more neighborhoods (30) were classed as having satisfactory infrastructures, with 20 neighborhoods falling in the category of unsatisfactory infrastructures (see Figure 8.8).

Table 8.5: Conditional Probabilities for the Sanitation Perceived Quality Latent Variable

		Counts	Class 1	Class 2
Water	Bad	8	0	0.39
	Good	42	1	0.61
Sewerage	Bad	35	0.52	1
	Good	14	0.48	0
Garbage collection	Bad	22	0.33	0.6
	Good	28	0.67	0.4
Water cuts	Often	23	0.38	0.57
	Seldom	27	0.62	0.43

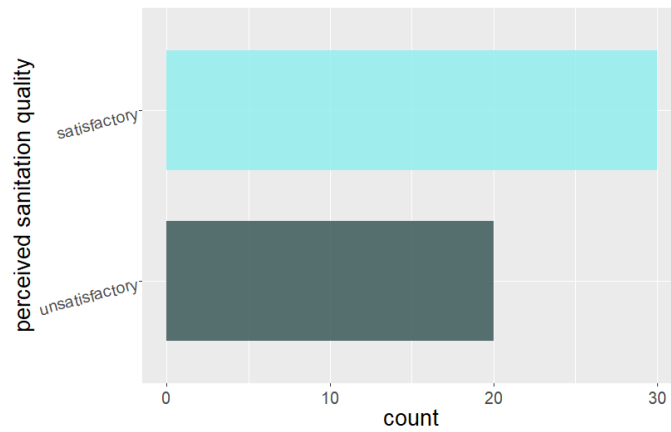


Figure 8.8: Perceived Quality of Neighborhood Sanitation

The presence of canals in the neighborhood was documented in the survey, as well as their continuity (if they are permanent or seasonal). A majority of neighborhoods (38 out of the 50) did not have any canals, 10 had permanent canals, while only 2 neighborhoods had a seasonal one.

In most of the sampled neighborhoods, malaria appeared to constitute a problem for the inhabitants (See Figure 8.9).

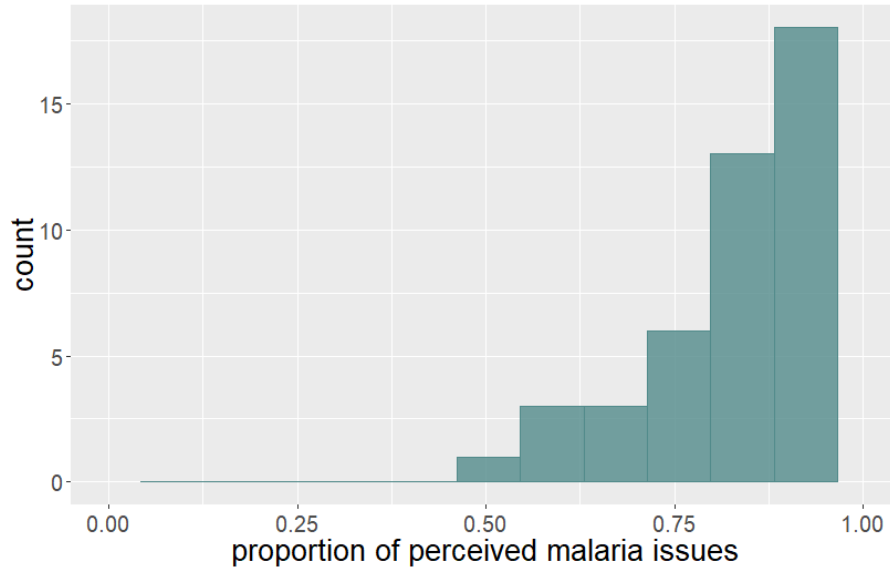


Figure 8.9: Perceived Malaria Issues by Neighborhood

The percentage of agreement with the statement “Malaria is a critical health problem in this neighborhood.” was generally high. However, there were discrepancies across neighborhoods, with the percentage of agreement ranging from just under half of the interviewees in the neighborhood (46%) to 100%. Such high percentages are likely to also be related to the moment when the data were collected, namely during and just after the rainy season, when transmission of mosquito-borne infection is at its highest.

8.2 The Dependent Variables: Incidence of water-related diseases

8.2.1 Univariate Results

Among the 7416 children sampled, 1151 (16%) experienced at least one diarrheal episode in the fifteen days preceding the survey, whereas 1742 (23%) experienced at least one febrile episode in the thirty days preceding the survey, with a the non-response rate of 1.4% and respectively 1.3%. The difference between febrile and diarrheal incidents may be, in part, due to the longer recall period

(30 days, as opposed to 15 days) and to the markedly higher transmission of mosquito-borne diseases during the period when data collection was organized.

Overall more than a third (2442 children) of the sample experienced either a mosquito-borne febrile or a diarrheal episode. Of these, almost a fifth (450 children) experienced both symptoms, while 701 and 1291 experienced only a diarrheal or only a febrile episode, respectively (see Figure 8.10).

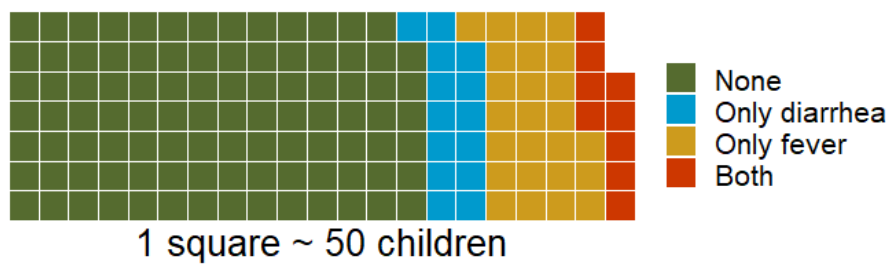


Figure 8.10: Incidence of Water-related Diseases

8.2.2 Bivariate Results

By Sex

With regard to distribution by sex, there doesn't seem to be any significant difference between boys and girls, neither in diarrheal nor in febrile incidence. 15% of girls and 16% of boys experienced a diarrheal episode, whereas 23% of both girls and boys each, experienced a febrile episode. Neither of the two associations (diarrheas with sex and fevers with sex) reaches any statistical significance.

The same holds true when looking at sex and age combined (see Figure 8.11). No major differences can be observed between girls and boys, although among the children for whom an illness was documented, slightly more girls (38, 6.4%) experienced both a febrile and a diarrheal episode than boys (212, 5.9%). Of the 4865 children

who had neither a febrile, nor a diarrheal occurrence, 2486 (51%) were girls and 2379 (49%) were boys.

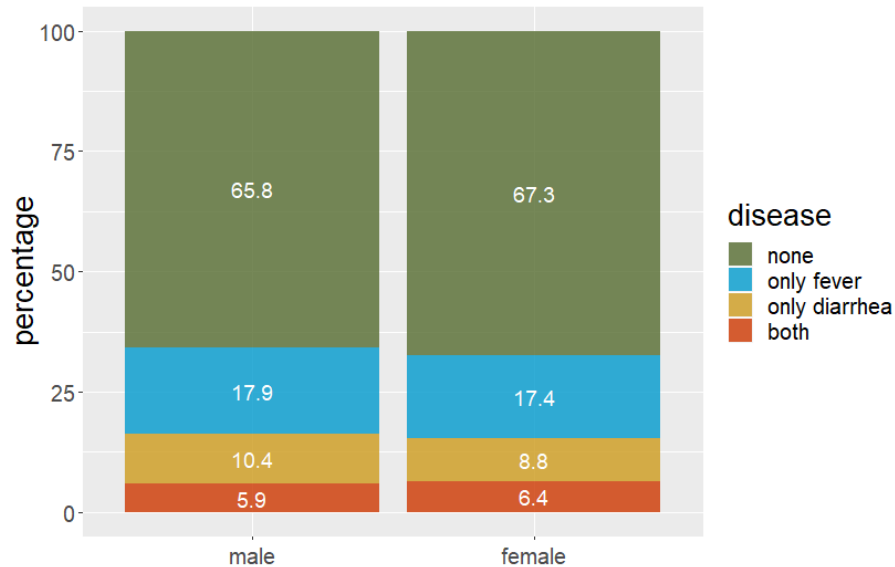


Figure 8.11: Water-related Diseases by Sex

By Age

If no major differences in water-related illnesses can be observed across the two sexes, the average age of children who did experience a symptom of water-related illnesses was slightly lower than the average age of those who didn't: 4.71/5.09 years for children who had a diarrheal/febrile episode, as opposed to 5.74/5.73 for children who didn't. Both associations were statistically significant at a 99% confidence interval.

Breaking up the sample by category of symptom, children who experienced both a diarrheal and a febrile episode were, on average, the youngest, on average aged 4.57, followed by children who experienced only a diarrheal episode (4.79 years old on average) and children who experienced only a febrile episode (5.27 years old on average). Children from the sample who experienced none of the symptoms were, on average, the oldest, at 5.86 years old. The same holds true when looking at the median ages (see Figure 8.12).

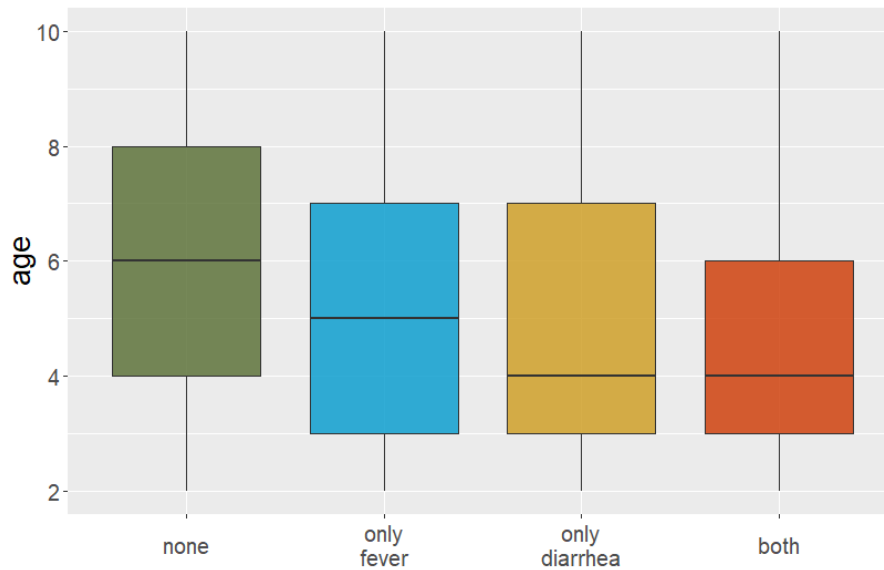


Figure 8.12: Water-related Diseases by Age

By Neighborhood

Overall incidence was 15.5% for diarrheal episodes and 23.8% for febrile episodes. However, these averages hide sizeable discrepancies across neighborhoods, ranging from 6.7% to 27.7% in the case of diarrheal episodes and from 10% to 36.7% in the case of febrile episodes. When taking the two symptoms separately, the incidence of only diarrheal episodes ranged between 1% and 19%, that of only febrile episodes was generally higher, between 7% and 33%, while most neighborhoods had low prevalences of both symptoms, ranging from 0% to 12% (see Figure 8.13).

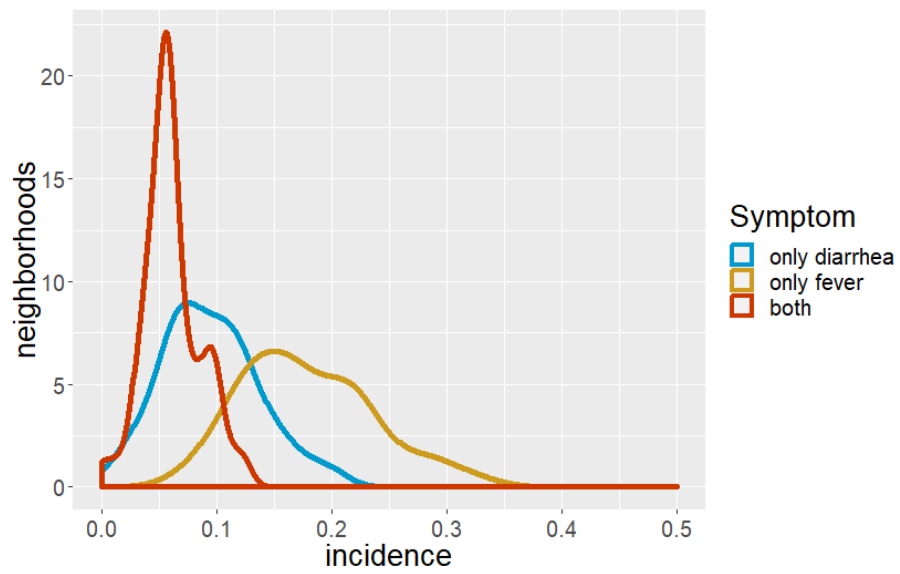


Figure 8.13: Water-related Diseases by Neighborhood

Chapter 9

Determinants of Water-related Diseases

The following pages detail the main findings of this study, both quantitative and qualitative, grouped into four large groups: demographic, socio-economic, behavioral and environmental determinants. The general statistical models which look at risk factors for symptoms of water-related diseases (diarrheal and febrile episodes) in children aged 2 to 10 in Dakar are presented here. Complementary to that, I will synthesize the outcome of the interviews conducted in four chosen neighborhoods of Dakar, aiming to provide possible insights and explanations regarding individual or household practices and particular living conditions in those neighborhoods¹. I have chosen this manner of presenting this study's main results because the two approaches I have employed, the quantitative and the qualitative, largely revolve around the same themes and have complementary roles in explaining the mix and interdependence between the surroundings and the conduct, with regard to water-related diseases.

The quantitative analysis laid out a broader picture of the web of determinants for children's water-related diarrheal and febrile episodes. A series of models successively add variables pertaining

¹For map locations of each of the four neighborhoods where the interviews took place, see Fig 10.5. For the demographic characteristics of each interviewee, see Appendix D

to each level of analysis. Thus, after the initial null model (without any explanatory variable), the second model adds variables related to the child and the mother/carer, while the third and fourth/fifth models add variables pertaining to the domestic and neighborhood levels, respectively. The reason for such a strategy, from a statistical point of view, is related to the limitations of statistical analysis in general: assessing parameters of a distribution based on a sample drawn from that distribution, allows to determine associations among variables, but not direct causality (Pearl 2010). Thus, regression analyses allow to establish associations between what is considered as the “outcome” variable and various covariates; however, from a theoretical standpoint, they do not determine that a causal relationship is behind these associations, since there is no random assignment mechanism with regard to the covariates considered.

In this context, the stepwise strategy of adding blocks of variables into a regression model allows to test whether adding certain covariates is necessary or useful or not, in the sense of contributing to explain the variability in the outcome variable. Thus, it permits progressive model enhancement, sifting through large numbers of potential independent variables. As determining strict causation is not possible with standard statistical analysis, stepwise addition of variables makes it possible to see whether and how adding each level and set of variables changes the effect of a previous variable or level of analysis. The stepwise inclusion of variables in the models also allows to test for potential interactions and confounding factors. This yields a more accurate and comprehensive view of the phenomenon, by understanding the potential inter-relations between factors and spheres, which was one of the goals of this thesis: of particular interest were the possible links between environment and behavior and those between sanitation facilities of the household and the sanitation infrastructures present in the area.

The multilevel approach used in this analysis permits to control for factors pertaining to the higher levels of analysis (household and neighborhood), as well as to single out the neighborhoods which distinguish themselves from the rest, either by a markedly different (with better or worse) than expected situation in terms of disease, all while controlling for the covariates of interest.

Subsequently, the qualitative analysis delved further into the mechanisms of determination to establish, on the one hand, whether the neighborhoods selected had specific properties which made them stand out compared to the general context of Dakar and, on the other hand, whether there were factors overlooked by the statistical analysis and which could further clarify what puts children at risk for water-related diseases.

This chapter will neither discuss random effects from the multilevel models, nor lay out results regarding landscape-related characteristics of the neighborhood, aside from very general observations, added here primarily due to their link to the other two levels of analysis (the individual and the household). Since the relative role of the higher levels (household and neighborhood) constitutes one of the focal points of the current study, a more in-depth look at this aspect will be presented in the following chapter, with both quantitative results and qualitative material (interviews and photographic material).

Tables 9.1 and 9.2 summarize the results of logistic regression models for diarrheal and febrile episodes in children from the Dakar region. In both cases, the set of models was constructed starting from the null model (without covariates) and successively adding variables pertaining to the next level up. Thus, model (1) presents the odds ratios of the null model, with no explanatory variable. Model (2) adds individual variables (the child and the mother/carer), model (3) also includes variables related to the household and dwelling, whereas model (4) follows through with variables pertaining to the neighborhood where the child lives. Since for febrile episodes I used an additional variable, a synthetic indicator measuring households' opinion of malaria in their neighborhood, a fifth model (5) was added in the quantitative analysis of febrile episodes, which adds the synthetic indicator to model (4). The reasoning behind this logic of subsequently adding variables pertaining to the next level up was to identify potential interactions between determinants situated at different levels or possible shifts in the effects of one level, when accounting for the subsequent one. Since each time Model (1) does not contain any covariate, for the sake of parsimony in terms of space, it will not be shown here, but rather in Chapter 10, where I will be presenting

the random effects of these models.

Another aspect to be noted is that Tables 9.1 and 9.2 do not present diarrheal and febrile episodes in a mutually exclusive way. That is to say, the 450 children who experienced both a diarrheal and a febrile episode are counted as both having had a diarrheal episode in the previous 15 days in Table 9.1 and as having had a febrile episode in the previous 30 days in Table 9.2. While the occurrence of the two episodes in the same child may be unrelated, there is also a possibility that they are related or even caused by the same pathogen. This is why, in Chapter 12, I will be analyzing the specific factors associated with the occurrence of both symptoms.

Table 9.1: Determinants of Diarrheal Episodes (Odds Ratios)

		mean	(2)	(3)	(4)
Child's sex (male)		49%			
	female	51%	0.97	0.97	0.97
Child's age		5.6	0.84***	0.84***	0.84***
Mother's age		34	1	1	1
Mother is literate (yes)		48%			
	no	52%	1.03	0.92	0.91
Mother's occupation (housewife)		51%			
	employed	45%	1.1	1.1	1.1
	other	4%	1.48**	1.5**	1.49**
Household wealth (high)		6%			
	average	51%		1.22	1.22
	low	43%		1.56**	1.56**
Health literacy (high)		75%			
	low	25%		1.26***	1.25***
Housing amenities (improved)		51%			
	unimproved	49%		1.2**	1.21**
Sanitation coverage (complete)		58%			
	incomplete	42%			1.08
Sanitation perception (high)		60%			
	low	40%			0.96
Constant			0.4***	0.26***	0.25***
Children			7280	7280	7280
Households			2945	2945	2945
Neighborhoods			50	50	50
<i>Note:</i>			*p<0.1; **p<0.05; ***p<0.01		

For both outcomes, across the whole set of four/five models, the odds ratios remained very stable. This indicates that the associational structure of the model is likely to be robust, since by adding new covariates, the coefficients and signs of the existing covariates either remained the same or did not considerably change. There are therefore good reasons to believe that the effects of the covariates considered in the models are, to a large degree, independent and one covariate does not significantly influence the impact of the other covariates.

Table 9.2: Determinants of Febrile Episodes (Odds Ratios)

		mean	(2)	(3)	(4)	(5)
Child's sex (male)		49%				
	female	51%	1.02	1.02	1.02	1.02
Child's age		5.6	0.9***	0.9***	0.9***	0.9***
Mother's age		34	1.00	1.00	1.00	1.00
Mother is literate (yes)		48%				
	no	52%	0.88**	0.87**	0.86**	0.86**
Mother's occupation (housewife)		51%				
	employed	45%	1.11*	1.11*	1.1	1.11
	other	4%	0.94	0.94	0.94	0.95
Household wealth (high)		6%				
	average	51%		1.35**	1.36**	1.34**
	low	43%		1.27	1.29	1.27
Health literacy (high)		75%				
	low	25%		1.15**	1.16**	1.15**
Mosquito protection (none)		4%				
	at least nets	53%		1.83***	1.79***	1.68**
	other measures	43%		1.92***	1.9***	1.82***
Housing amenities (improved)		51%				
	unimproved	49%		1	0.99	0.95
Sanitation coverage (complete)		58%				
	incomplete	42%			0.92	0.91
Sanitation perception (high)		60%				
	low	40%			1.29**	1.19*
Canal (none)		76%				
	seasonal	4%			1.48*	1.41
	permanent	20%			1.14	1.13
% perceived malaria issue		85%				2.37**
Constant			0.52***	0.22***	0.2***	0.11***

Continued on next page

Table 9.2 – *Continued from previous page*

	mean	(2)	(3)	(4)	(5)
Children	7,292	7,292	7,292	7,292	7,292
Households	2,948	2,948	2,948	2,948	2,948
Neighborhoods	50	50	50	50	50
<i>Note:</i>		*p<0.1; **p<0.05; ***p<0.01			

9.1 Demographic Factors

The demographic determinants pertaining to the individual/carer level considered here are the child's sex and the age (of the child and of their mother/carer), which were used as control variables. Given existing literature regarding the role of demographic characteristics on child infectious health in general, the expectation in the current study was that increased age would provide protection against water-related diseases, whereas the child's sex would not significantly impact the odds of disease.

Both indicators confirmed these expectations, with being a boy or a girl seeming to not have an impact on the odds of water-related diseases, be it manifested by a diarrheal or a febrile episode. However, while gender did not have a significant impact on the health outcomes considered, age did: being an older child was less associated with disease than being a younger one and this linear negative relationship was statistically significant at a 99% confidence interval for both indicators used. Each additional year of the child's life would lead to a decrease of 16% in the odds of a diarrheal infection and to a decrease of 10% in the odds of a febrile infection. The mother's or carer's age, on the other hand, seemed to have no impact on the variables of interest, with odds ratios of one, for both outcome variables.

9.2 Socio-economic Factors

Socio-economic factors were used as control covariates in the present research, examining the ability to read/write and the occupation of the child's primary minder, as well as the category of wealth of the household. In most studies, both having a literate primary carer

and having an increased level of wealth in the household are associated with lower risks regarding water-related diseases. Concerning the primary carer's occupation, as exposed in Chapter 4, findings are mixed and no clear relationship has been established.

The ACTU-PALU data do not suggest any of the indicators regarding the child's mother or carer to have a significant impact on increasing or reducing the odds of having experienced a diarrheal episode, as opposed to not having experienced it, with the exception of being in the category "other" regarding occupation. This category includes mostly women who are students or apprentices, who do odd jobs or household aids. Consequently, the increased odds for diarrhea associated with having a carer in this category (which are about 50% higher) may in fact express a slightly socially disadvantaged situation and less stable occupations.

Regarding febrile episodes however, having a literate mother or carer was statistically significantly associated with a somewhat higher odds of febrile episodes in children. Thus, children cared for by illiterate women had odds of a febrile episode around 12-14% lower than those cared for by literate women. On a first view, this appears counter-intuitive, given that in general, maternal education has a protective impact on child health (which is often mediated by income) (Mosley and Chen 1984). One hypothesis as to why this happens may lie in the declarative nature of the explained variable, since more educated families may have a higher propensities to notice and/or report disease (Filmer 2005). Another hypothesis is that employed secondary carers (such as nannies) are more likely to be employed by more educated and wealthier families. In this case, the presence of a nanny may interact with the mother's education and limit the expected positive impact of maternal education. This hypothesis would also explain why having an employed mother, as opposed to a housewife, was associated with statistically significantly higher odds (1.11, significant at a 90% C.I. in Models (2) and (3)) of a febrile episode in children.

Consequently, I have proceeded to test each of the aforementioned hypotheses. The first hypothesis was that of a reporting bias, which would be inherent to declarative data and which would consist of under-reporting of febrile episodes by illiterate carers or carers with-

out formal education. If such reporting bias were true, one would expect to obtain similar results when using other data as well. Consequently, I have tested the association between febrile episodes and the mother's education level using the Senegalese 2008-2009 Malaria Indicator Survey (MIS) from the DHS program² (Ministère de la Santé, de la Prévention et de l'Hygiène Publique, Sénégal et al. 2009).

Table 9.3: Association between the mother's education level and the occurrence of a febrile episode DHS-MIS Senegal 2008-2009)

Mother's education	Fever		Total
	No	Yes	
None	6160.85 69.28%	2731.39 30.72%	8892.25 100%
Primary	1948.30 64.37%	1078.56 35.63%	3026.86 100%
Secondary or higher	696.30 68.97%	313.21 31.03%	1009.51 100%
Total	8805.46 68.11%	4123.16 31.89%	12928.62 100%

$$\chi^2 = 30.765, \text{ df} = 2, \text{ p} = 0.003$$

As Table 9.3 shows, the statistically significant association between having an educated mother and a reported febrile episode is maintained in DHS data³. This appears to confirm the hypothesis of a slight reporting bias, inherent to most surveys. As the majority of surveys measure the occurrence of infectious diseases by asking respondents whether or not they (or their children) experienced the symptoms associated with the disease in question, it is likely that literate mothers would notice more (and hence report more) febrile episodes in their children.

The second hypothesis was that literate mothers/carers are more likely to have higher socio-economic status and wealth than their illiterate counterparts and also more likely to employ nannies or secondary carers for their children. If these secondary carers, aside

²Weighted data

³The same association holds true when limiting the observations to inhabitants of the Dakar region. However, probably due to the smaller sample size, it does not reach statistical significance

from being less educated, are also younger or less experienced, the children would be faced, from this point of view, with slightly more elevated risks than those of illiterate mothers/carers, who would not employ secondary carers.

In order to test this hypothesis I have proceeded to three steps, using both a quantitative and a qualitative approach. First, the potential existence of an association between the primary carer's ability to read/write and the family's wealth needed to be established. Second, if this association was statistically significant and went in the expected direction (literate mothers/carers are more likely to live in wealthier households), a potentially confounding role of the household wealth needed to be tested. The aim here was to investigate whether, if the models presented in Table 9.2 did not include the household's wealth status, the apparently protective role of an illiterate mother/carer would be reversed or at least cancelled. Third, I wanted to investigate, more in depth, the childcare practices of families, with a focus on finding out whether or not wealthier families tended to resort more to secondary childminders and to briefly delve into the characteristics of these secondary childminders. This aspect was particularly useful if the apparently protective effect of an illiterate mother/carer was, indeed, dependent of the household wealth.

Consequently, I first tested the statistical association between the mother's/carer's ability to read and write and the household wealth, expecting to find a positive relationship.

Table 9.4: Association between the mother's/primary carer's ability to read/write and the household's wealth

Mother/carer can read/write	Household wealth			Total
	High	Average	Low	
Yes	199 10.24%	1192 61.32%	533 28.45%	1944 100%
No	46 2.22%	1053 47.04%	976 50.75%	989 100%
Total	245 6.1%	2168 53.94%	1606 39.96%	4019 100%

$$\chi^2 = 268.749, \text{ df} = 2, p < 0.000$$

As Table 9.4 shows, this association did indeed prove to be both pos-

itive and statistically significant, which means that literate mothers/carers do tend to belong to wealthier households more often than their illiterate counterparts.

Secondly, the potentially confounding role of the family's wealth needed to be tested, by excluding the variable related to wealth from the models and analyzing whether or not there is a shift in the effect of the mother's/carer's ability to read/write on febrile episodes.

Table 9.5: Effects of the mother's/carer's ability to read/write, not accounting for household wealth status (Odds Ratios)

	(2)	(3)	(4)	(5)
Mother is literate (yes)				
no	0.88**	0.87**	0.87**	0.86**
<i>Note:</i> *p<0.1; **p<0.05; ***p<0.01				

The results presented in Table 9.5 refer to the same models as those presented in Table 9.2, with the only difference that the models presented in Table 9.5 do not include the household wealth as covariate. Moreover, since none of the other effects exhibited any notable change compared to those in Table 9.2, they are not shown here. This contradicts the hypothesis of a confounding role played by the household wealth and it thus appears that the apparently protective role of an illiterate mother/carer is not dependent of the household wealth.

Thirdly, I further investigated, by qualitative methods, the aspect of secondary childminders and their characteristics. The goal was to identify if there were some unaccounted for parameters, which could interact with the primary carer's socio-economic status and alter the usual protective role of the mother's education on the child's health.

The starting point of the investigation was the scenario that more educated or wealthier households would want to and could afford to hire a nanny to care for their children. Since a nanny's level of education is usually low, this could then explain the lack of significance of the mother's education in the statistical models explaining a diarrheal episode and a counter-intuitive relationship in those ex-

plaining a febrile episode⁴.

Hence, in the interview structure, I included a section dedicated to the children of the households (their ages, which influence their needs for care) and the child carers of the household (whether or not they were family or household members and some information about their social background).

Throughout all of the interviews, it was usually obvious that, as in most African contexts, mothers were the primary carer of their children. However, the interviews also showed that, at least in the families I met, it wasn't only the wealthier households which made use of a secondary child carer. Who this secondary child carer was, did indeed depend on the family's revenue and social status.

Families without a nanny

Where a nanny or maid was not available in the household, it was generally other, usually female, family members who also participated in taking care of younger children. Moreover, some families split the childcare-related chores among the several mothers in the house, as one interviewer explained:

Adja (26, woman, Unité 8)

Interviewer: Alright, and who takes care of children here?

Adja: We, their mothers...

Interviewer: I see, and how do you do, each one takes care of her own children?

Adja: We take care of everyone... What one does for her own children, she can do it for the other children as well, we help each other.

Another interviewée also said that, while each mother was the main care-giver for her children, she did resort to other family members, including the older children to mind her younger children when she was not available. Also, she shared child-rearing tasks with her sister-in-law, who lived in the same house.

Inter-generational solidarity, where either grand-parents or older siblings take care of young children, was a rather wide-spread practice among the families I interviewed. One of the respondents de-

⁴See Tables 9.1 and 9.2

scribed her family's approach to having her children cared for during workdays. She also explained to us that the main reason for this strategy was that, since she could not afford to pay for childcare, she resorted to sending her children to her mother's house, while she was at work:

Sawdiatou (25, woman, Unité 8)

Sawdiatou: Here, it's only me who has my children with me... I have 2 and a child who is breastfed too. My house-mate has 2 children but they don't stay here: I mean, she goes to work and drops her children off at her mother's house until she comes back to get them back... they only spend the night here.

Interviewer: And your children, they spend the day at home?

Sawdiatou: Yes, they do...

Interviewer: Who takes care of them while you're at work?

Sawdiatou: I drop them off at their grandmother's... I work from 17:00 until dusk... They left there not long ago.

Interviewer: And how old are they?

Sawdiatou: One is 11 years old, the other is 4 years old, they are boys... and the youngest is 9 months old, it's her who's breastfed.

Interviewer: Okay... so the children go to your mother's house until you finish work and you collect them?

Sawdiatou: Yes... sometimes, if they realize that it's time to go home, they even come back by themselves...

Interviewer: And the little one goes there as well?

Sawdiatou: Yes, she is also at my mother's place.

Interviewer: Okay... and at home, is there anyone helping you? Like a maid?

Sawdiatou: No, at home I'm alone... you know, we lack the means for it...

Interviewer: And you don't have a niece or an extended family member that helps you at home?

Sawdiatou: No, there's only me, my husband and my children... because life is difficult nowadays.

As mentioned before, aside from splitting childcare among several mothers living in the same household and involving grand-parents

as secondary child-minders, in some households older children also helped with household chores and watched over their younger siblings:

Selbé (60, woman, Dalifort)

Selbé: Ah, my granddaughter there, she's a volunteer. When she gets up in the morning, she makes sure her mother's room is in a good state, she sweeps, she does the dishes and she takes care of her little brothers.

Families with a nanny

If a nanny was available for the family – usually a young girl, either still a student or just having finished her studies – she usually slept in the same house during the week and generally left each fortnight. Her tasks, both in terms of household chores and in terms of childcare, varied from one family to another. For example, we met Coura, a woman from Soprim 1, while she was at work, cooking and selling doughnuts and she explained she had a maid who helped with childcare:

Coura (27, woman, Soprim)

Coura: She gives them their bath... gets them dressed... but it's me who manages the kitchen...

Interviewer: So when you are busy cooking, is it her who takes care of the children?

Coura: Yes.

Interviewer: Okay... and who feeds them?

Coura: Sometimes it's the maid... if I'm a little busy...

Interviewer:... the maid, does she sleep over?

Coura: Yes.

Interviewer: She goes back every week or...?

Coura: She goes home every 15 days...

Interviewer: And how old is she, the maid?

Coura: She's 15 years old...

Interviewer: Did she go to school, the maid?

Coura: Yes...

Interviewer: Do you know up to what level?

Coura: No.

Interviewer: Okay... Does she speak French?

Coura: No.

Interviewer: Does she help the children when they have homework?

Coura: Yes, she does.

As was the case of Coura, maids usually provided supplementary childcare for the family, alongside housework. Thus, it looks like the boundaries between a housekeeper and a nanny were somewhat blurred in the social contexts I experienced throughout these interviews. Nevertheless, it seemed that women generally took pride in their cooking, so – as in Coura’s case – the maid was generally not in charge of preparing the meals for the family. Moreover, although in some cases the children spent most of the day with the nanny, most respondents made it quite clear that mothers retained their primary care-giving role and authority.

One of the interviewees, Khadija, was a nanny and a maid. She also took care of the three children in the house (aged 10, 9 and 3), whose mother was a housewife.

Aged 19, Khadija had finished primary school and stopped at the 6th grade. Subsequently, she had a child of her own, a girl aged now a year and a half. Since she lived with the family she worked for, she had left her baby girl with family in her home village:

Khadija (19, woman, Soprim)

Khadija: I am both housekeeper and nanny.

Interviewer: Where do you work?

Khadija: Right here, behind...

Interviewer: How long have you been working here?

Khadija: It’s been less than a year.

[...]

Interviewer: You sleep here?

Khadija: Yes.

Interviewer: You go back home every week or...?

Khadija: No, I reside here...

[...]

Interviewer: Okay... and who cares for the children?

Khadija: The mother of one of them is sitting there in front of the door of the house... She takes care of one of them, for the others I do their laundry...

Interviewer: Okay. Who bathes them?

Khadija: Themselves.

Interviewer: And the youngest?

Khadija: It's me who takes care of him, or his mother...

Interviewer: Okay... when you take care of children, what do you do, generally?

*Khadija: I take care of the linen for the youngest... When I sweep, he comes to me, talks to me, laughs. I pamper him and... you know, with children you have to play...
[...]*

Interviewer: Okay... are you and the family you work for related to each other?

Khadija: We are neighbors in the village, our two houses face each other.

Interviewer: Ah, I see... So it was on this account that you left the village to come and live with them here?

Khadija: Yes...

Looking a bit further into the phenomenon, there is evidence of this sort of “au pair” scheme being quite widespread in urban Senegal. Mainly young girls, most often with little or no schooling are paid to come and live with families, providing housework and childcare (Delaunay and Enel 2009). Generally, the girls originate from rural areas and come to work either on a seasonal basis (during the school holidays) or on a permanent basis (thus dropping out of school altogether) and are usually aged between 10 and 17 years old (Coulibaly-Tandian 2012).

In many cases, the young girl is paid a very low wage, but they mean, for the girl's family, one less mouth to feed (Delaunay and Enel 2009). Generally, the young girl is either in some way related (a distant relative) to the family for whom she comes to work or the families involved are acquaintances. In Khadija's case, the family she now worked for were neighbors and it was as a result of this relationship that she had come to reside in Dakar, leaving her child with the grandmother.

So, it seems that if families could afford it, they did tend to employ a maid, who would then be in charge with (some of the) household and childcare tasks. But if families could not afford such paid help, the adage whereby "it takes a whole village to raise a child" does remain true, at least in the case of the families interviewed for

this study. And, in Dakar’s urban setting, the village in question was largely constituted of close or extended family members, either living in the same dwelling or nearby.

This, like the quantitative analysis presented in Table 9.5, does not appear to support the hypothesis that the apparent risk associated with having a literate mother/carer is due to secondary childminders. If such a relationship exists, it does not appear to be strong enough to explain, in itself, the counter-intuitive effects of the mother’s/carer’s ability to read/write. In this context and given the similar results obtained using DHS data, it would seem more plausible that the apparent protective role of having an illiterate mother/carer is, for the most part, due to under-reporting by less educated primary carers. Illiterate mothers may be less likely to notice some febrile episodes in their children and therefore less likely to report them, than literate mothers.

In terms of household wealth, results generally confirm expectations, in that living in a less affluent household brings about additional health risks for children. Compared to households from the “wealthy” category, the other two categories were associated with an increase in the incidence of water-related diseases in the quantitative analysis. For diarrheal diseases, the relationship was significant only in the case of the poorer households (with over half – 56% – increased odds) and not in the case of households in the average category. The opposite was true for febrile episodes: here the relationship was significant in the case of average-wealth households (which lead to a 34%-36% increase in odds compared to a wealthy one), while in the case of poorer households, the association did not reach statistical significance.

9.3 Behavioral Factors

The behavioral factors considered in this study, refer to health literacy and medical behavior, to hygiene and to anti-mosquito measures. As behavior is one of the focal points of the present study, behavioral determinants are first addressed in the statistical analysis and subsequently in the interviews, under the hypothesis that increased health literacy and protection measures (hygiene and mosquito bite prevention) provide protection against water-related

disease symptoms. Since the quantitative data on behavior mostly covered aspects related to knowledge and practices related to disease and medicine, I have opted to complement this by adding a section on hygiene in the household in the interview structure.

Health Literacy

The health literacy and conduct of the primary carer was explored as a latent variable in the quantitative analysis, in order to assess whether parents' knowledge, attitudes and practices with regard to health and medicine could be associated with a reduction of infection. In all of the models which include this latent variable, health literacy had a statistically significant impact: low health literacy was associated with respectively 26% and 25% increased odds of diarrheal episodes in children, whereas for febrile episodes the increase in odds was of 15% and 16%. This prompted me to further investigate, in the interviews, the mechanisms by which individual or family conduct can impact on water-related diseases. Consequently, two main themes emerged: attitudes and behavior with regard to hygiene and the potential role of the neighborhood on health literacy, meaning the possible interactions with neighbors and their impact on individual or family health-related choices. These two main themes were addressed in the qualitative section of this study and the following pages present the main findings concerning the two aspects.

Hygiene: water storage and treatment

Many of the interviewees from the four neighborhoods visited were not content with the quality of tap water, with recurring complaints about either a reddish tint to the water or deposits forming on the bottom of the container where drinking water was kept:

Niouma (60, woman, Soprim 1)

Niouma: The water is not at all fit enough for drinking. Because when you collect it in bottles and put it in the fridge, there are deposits that form underneath; it looks like clay...

Interviewer: And before drinking it, do you add bleach?

Niouma: No, personally I don't add anything. There is a time of day when the water is very clear and another

where it's not good...

Interviewer: Okay... does this have any health implications, for children for example?

Niouma: Sometimes there are consequences of course, both on the health of adults and on that of children... the father of the family buys bottled water: he drinks it and the children also.

Some interviewees did not treat the water in any way before drinking, despite noticing a reddish color and deposits. However, most households we interviewed in similar situations, kept their drinking water in bottles and/or buckets and some left it for a few hours to overnight, in order for deposits to set on the bottom of the container.

Mame (55, woman, Fith Mith)

Interviewer: Here at home, do you have a tap?

Mame: Yes, we do.

Interviewer: And what is the tap water that you use for your laundry?

Mame: Yes, and for drinking and all.

Interviewer: And what do you think of the quality of the water?

Mame: Sometimes, the water looks reddish. It has a red tint and looks like kinkeliba⁵. If you let it rest for a moment, you see that some sort of clay residue forms underneath and when the water is like that, we collect it during night time, to let it rest until the next day in order to decant it.

Interviewer: Ah, to be able to drink it?

Mame: Yes.

Some households routinely added a few drops of bleach to drinking water, but none of the households interviewed declared boiling water before consumption:

Selbé (60, woman, Dalifort)

Selbé: You know, we are Fulani, we have buckets. We also have those white bottles over there, with lids, and we

⁵herbal tea made by steeping *Combretum micranthum* leaves

use those for drinking. We clean them well, we fill them up, add 3 drops of bleach and we store them to use for drinking.

In many cases, interviewees seemed to associate the appearance of the water to its potableness. Thus, the absence of color or odor lead respondents to consider it microbiologically clean, in which case they were more likely to drink it without any prior treatment, whereas if the water had deposits, then most respondents considered it to be dirty or unfit for drinking as it was.

Sawdiatou (25, woman, Unité 8)

Interviewer: What do you think of the quality of the water?

Sawdiatou: It is fit to drink...

Interviewer: Do you use this water for all your household needs as well as for drinking?

Sawdiatou: Yes.

Interviewer: When you drink it, do you add something to it or you don't have to treat it before drinking it?

Sawdiatou: No, it's not worth adding anything to it or treating it because it's clean.

Hygiene: garbage storage

With regard to garbage storage in the house, households usually had a trash bin with a lid, which they kept in a more secluded space:

Sawdiatou (25, woman, Unité 8)

Interviewer: In relation to garbage, where were you saying you keep them in the house?

Sawdiatou: Next to the toilet... the bin has a lid and all... and we clean it periodically with bleach... and there is a bag that we put in, before putting the garbage.

In the event they had to store the trash for more than one day, families would tie the bag and some households used bleach to prevent the proliferation of bacteria around the bag:

Khadija (19, woman, Soprim)

Interviewer: For example if the garbage truck does not pass one day, how do you do with your garbage?

Khadija: Yes... we put it in the trash bin and we close well... or we put it in a bag that we tie well to avoid flies, then we put it somewhere where it's covered and we wait for the truck to come.

Hygiene: food

Knowing that questions related to handwashing often yield socially desirable answers, I focused mainly on fruit and vegetable washing or peeling. However, asking interviewees about their practices with regard to food preparation had the same result: respondents seemed to know what was expected of them in terms of washing fruit and vegetables and they seemed scrupulously conform to the norm of washing, peeling or cooking produce. Therefore, in order to not risk generating additional bias into other questions, I renounced broaching this topic after a few socially desirable answers:

Selbé (60, woman, Dalifort)

Interviewer: Regarding the foodstuffs you eat, how do you prepare them before eating?

Selbé: I don't cook anymore, it's my children and my daughters-in-law who do it these days. But I see that they prepare well the vegetables, they clean them well before cooking; they use bleached water (bleach granules diluted in water) to rinse the vegetables before cooking.

One aspect which is important to bear in mind is that most of the times, individual behavior was strongly influenced by the conditions in which the individual lived. Thus, a family that did not judge the quality of the water they had access to as satisfactory, was more likely to treat it prior to drinking than a family that benefited from infrastructure which they judged to be adequate. Of course, different individuals may well have different perceptions of what constitutes acceptable provision and what is considered as sufficient by one, can be less than for another. Thus, it would seem that the aspect of behavior is in close relation to that of the domestic environment at the household level and to that of sanitation at the

neighborhood level⁶.

Neighbors and Their Influence on Behavior

The topic of neighbors was broached during the interviews, with the purpose of establishing whether or not people had repeated contact (aside from greetings when meeting by chance) with those living in the same area. More precisely, I wanted to know if people were likely to discuss with their neighbors aspects related to children, childcare, child health and medical issues and whether they were thus likely to be influenced in their behavior by their neighbors.

The underlying hypothesis was that small geographic areas would be populated by more or less similar people in terms of socio-economic status and background. In the event that people were also prone to share information with those living close to them, the two aspects would then lead to a certain degree of homogeny, across small geographical areas, with regard to attitudes and behavior towards children and health. Thus, social relations in the community could be expected to somewhat increase interest or knowledge with regard to health (Bender et al. 2015).

The interviews painted a somewhat different image of the relationships which form between people living near each other: although some people did know their neighbors and kept more or less close relationships with them, they were a minority. For most, contact with their neighbors was limited to the usual greetings or the odd small talk every now and then.

One interviewee, upon our insistence on asking about the conversations she has with her neighbors, explained that, as opposed to rural areas, relationships between neighbors in urban settings tend to be less profound and that people tend to take less interest in the lives of those around them:

Adja (26, woman, Unité 8)

Adja: We pass each other in the street, we greet each other...

Interviewer: Do you sometimes chat? Do you have good relations?

⁶See also section 9.4 of this chapter.

Adja: Yes, it happens...

Interviewer: Okay... and what do you usually talk about with your neighbors?

Adja: (laughs) You know here, relations are superficial between neighbors... it's not like in the suburbs where strong bonds are built... everyone goes about their own business here.

Those who do have closer contact with their neighbors, although they do exist, were, at least in our experience, quite rare: few people tended to talk to their neighbors, aside from polite exchanges of salutations. Moreover, among the interviewees there was only one person who said that she and her neighbors were actively involved and had recurring conversations:

Selbé (60, woman, Dalifort)

Selbé: I know many of them, but there are others that I know by sight but not by name.

Interviewer: And you find yourself talking to them or meeting up with them?

Selbé: Yes, we sometimes chat, we have a good relationship and all. If someone has an event or ceremony and we are notified, we organize, we help each other, we contribute, we participate to make the event a success.

Interviewer: Do you discuss issues related to children and their education?

Selbé: It can happen. Someone may put up a sunshade and invite us to chat, for example, about pregnancy, breastfeeding or birth, about all that.

These results, although they don't claim to be representative of the whole city, present nevertheless an image of Dakar where neighbors don't keep close contact with each other and where vicinity relationships remain at a rather superficial level. This would then refute the hypothesis that medical and health knowledge and behaviors propagate across the city's neighborhoods by means of regular conversations between people living in the same geographical area.

Anti-mosquito measures

Most of Senegal (and all of the Dakar region) experiences a wet season, during which mosquitoes breed and thus their number significantly increases. It is therefore also the season with the highest transmission of mosquito-borne diseases.

As a result and in an attempt to limit the spread of malaria in particular, campaigns to distribute LLITNs have been conducted throughout the city (J. I. Thwing et al. 2011). Pregnant women and young children were particularly targeted, as categories of population at higher risk for infection.

In the current study, the variable assessing means of protection against mosquito bites had a strong and statistically significant relationship with children's febrile episodes. However, this relationship was contrary to what one would normally expect, knowing that mosquito repellents in general and bed nets in particular keep mosquitoes at bay from human blood meals (V. Robert et al. 2003).

A possible explanation for this counter-intuitive association would be that, as Thomson and colleagues found, there is a strong correlation between mosquito net usage and vector density in an area (1994). Similarly, the main reason for not using a mosquito net, given by individuals in a study by Iwashita and colleagues (2010), was that "there are no mosquitoes". It seems perfectly sensible that individuals are more likely to take measures to protect themselves from mosquito bites, if mosquito bites constitute a concrete hazard.

This would lead to a situation of reverse causation, in that mosquito protection measures would thus be a function of mosquito presence in the area. Therefore, the presence of mosquitoes would be linked to both the explained (water-related disease) and the explanatory (vector protection) variables. Hence, I decided to further investigate this possible interaction between individual/household behavior and neighborhood environment both by quantitative and by qualitative analyses and the results yielded will be presented in chapter 11.

9.4 Environmental Factors

The environment considered here referred both to the household and to the area in the close vicinity of the household. As with behavioral factors, the environment constitutes one of the main themes of this study, under the starting assumption that better sanitation, both at the household and at the neighborhood levels, as well as the absence of canals in the area (as water bodies), constitute protective factors against water-related infections.

Since aspects such as sanitation are in close relationship between the two levels (sanitary amenities in the household depend on the available infrastructure in the neighborhood), both spheres needed to be concomitantly included in the research. As both provision and quality at the neighborhood level can be difficult to accurately assess through statistical data only, this topic was also addressed in the qualitative analysis.

Amenities and Sanitation

Sanitary facilities and general amenities played a significant role in both diarrheal and febrile episodes, but the level of analysis differed between the two. For diarrheas, children living in houses with unimproved amenities⁷ were 21% more likely than those living in houses with improved amenities to have experienced a diarrheal episode. However, when looking at potential determinants at the neighborhood level, neither the coverage, nor the perceived quality of the sanitary infrastructure seemed to have an impact on the odds of disease in children.

Conversely, the opposite was true when it came to fevers: household sanitation and facilities seemed to not significantly influence the occurrence of a febrile episode, in that those children living in dwellings with unimproved amenities did not differ much compared to those living in dwellings with improved amenities. However, at the neighborhood level, while the coverage of sanitary infrastructures did not significantly impact the odds of febrile episodes, its perceived quality did. Thus, living in areas where access to water, wastewater evacuation and solid waste collection were deemed

⁷these measured the type and reliability of the drinking water source, wastewater and solid waste facilities, as well as the roof and wall materials

unsatisfactory, was associated with a significant increase of almost 30% and almost 20% respectively, in the odds of having developed a vector-borne fever in children. Since the number of observations at this third level was small (50 neighborhoods) and in order to gain a more nuanced view of individuals' opinions about the sanitary infrastructure in their area, this topic was also addressed in the interviews.

Access to Water

Among the people we interviewed, most households had running water in the dwelling or compound and only two households had to buy water, as they did not have piped water. For both of these households, cost was a deterrent to using more water and they had to scale down their needs to be able to afford to buy water:

Fadima (56, woman, Dalifort)

Fadima: We have neither taps nor toilets.

Interviewer: Where do you buy water?

Fadima: At the surrounding (public) taps... there is one on this side, another on the other side.

Interviewer: How do you find the price of water?

Fadima: I buy water basins for 400 francs a day⁸. A basin is 50 francs.

Interviewer: Are those basins that you buy enough for all your needs?

Fadima: Yes, if I buy them at this time of the day, they can last until the same time the next day.

Interviewer: Would you want more water?

Fadima: Of course I would like more water because I have a large family.

[...]

Interviewer: And what do you think of the quality of the water you buy? Is it fit for drinking?

Fadima: Yes, it is. I am satisfied with it and even if I weren't, it's still this water that I would buy because I don't have the choice.

[...]

Interviewer: You said you didn't have taps at home. And

⁸One euro is worth around 660 West African francs

your neighbors, do they have taps?

Fadima: Yes, sometimes you can go get some water from them. This one has, that one too but here in the barracks nobody has taps.

Like Fadima in Dalifort, Safiétou in Fith Mith did not have running water anymore⁹ or and she either bought water from neighbors or asked them to give her some water for free:

Safiétou (42, woman, Fith Mith)

Safiétou: I actually ask for water... it bothers me a lot to be doing that.

Interviewer: Because you no longer have no tap at home?

Safiétou: It has been cut for a long time, since 6 years ago.

Interviewer: Why were you cut off?

Safiétou: Because of the unpaid bills.

Interviewer: Okay... do you buy the water or do you ask if they can offer it to you?

Safiétou: Sometimes I buy, other times I ask... because I can't buy all the time. But I buy much more often than not.

Interviewer: Do you have a public tap here where you buy water?

Safiétou: No, we buy from other neighbors.

Interviewer: And what do you think of the tap water, is it drinkable or not?

Safiétou: Sometimes it's clean, sometimes there are deposits in it.

Interviewer: Okay... do you manage to satisfy your needs in terms of water?

Safiétou: No, I don't... you lower your needs because you don't always have the money to pay for it.

Safiétou mentioned, as other interviewees, that the water she got from her neighbors' tap sometimes had deposits in it. As previously showed, the vast majority of respondents complained about the water quality (the most frequently mentioned issues were reddish color and deposits). Moreover, some interviewees also complained

⁹She had been disconnected due to unpaid bills

about water cuts, which meant that they were often compelled to find alternative sources of water:

Fatoumatou & Binta (60 & 24, women, Fith Mith)

Fatoumatou: When you arrived, there was a water cut.

Interviewer: Do the cuts last long here?

Binta: Sometimes yes, sometimes no...

Interviewer: And how do you manage in case of longer water cuts?

Binta: In that case... you don't know where to go except for the public pumps and there too the water is reddish.

[...]

Interviewer: Okay... and the water you collect at the pumps, can you use it for drinking?

Binta: No.

Interviewer: And what water do you drink then?

Binta: We have water reserves that we collect every day in these bottles and we use it for drinking.

Fatoumatou and Binta, two women living in the same house in Fith Mith, had one water tap in the dwelling, which was located in the yard.

When asked about the frequency of water cuts, they replied that there was no water when we arrived to their house, which hinted to the fact that water cuts were not unusual in their household. In those situations, although they could collect water for free from the communal pump, they did not judge its quality to be suitable for drinking, which meant that they had to daily stock up on water in case of a water cut.

Other interviewees also confessed to experiencing frequent water cuts: for example C, a 27-year old woman in Soprim 1 described them as occurring “not every day, but often”. In such situations interviewees resorted to alternative sources of water or to stocking up on drinking water through various methods:

Combé (22, woman, Dalifort)

Combé: Before there were almost no cuts but now there are a lot.

Interviewer: On average, how long can water cuts last

during the day?

Combé: It can be out all day long.

Interviewer: And how do you do in that case?

Combé: Some houses have wells around here, we go there.

Interviewer: Do you use this well water for drinking?

Combé: No, we save tap water in bottles so that in case of a cut we can use it for drinking.

In this context, although the vast majority of households officially had piped water (hence an improved water source), aside from the poor quality of tap water, they were often forced to resort to secondary or alternative water sources, due to the unreliability of their main source. This raises significant questions concerning the validity of estimating access to water by means of coverage of the piped water network in urban areas from developing countries. It also constitutes a potential source of bias for studies which address the relationship between such an improved, but unreliable water source and water-related diseases. Generally, water source is measured only in terms of the official, primary source, thus ignoring all such issues related to quality and reliability.

Wastewater

Wastewater management in general and sewerage in particular, seemed to cause the most dissatisfaction, out of the three infrastructures we interviewed people on (access to water, wastewater and solid waste). From talking to people, it seemed that larger areas missed connection to the sewerage system, than in the case of access to running water or to solid waste collection.

An interviewee from Dalifort, who was living in an area where improvement works had been carried out a few years before our interview, first pointed out this aspect: sanitation was still problematic, despite the recent revitalization of the neighborhood. Although she was generally content with the quality of life in the neighborhood since these works had taken place ¹⁰, she remained dissatisfied with the situation regarding wastewater. She described both the situa-

¹⁰the road where her house was located had been paved, the quality of water had considerably improved and the presence of mosquitoes had diminished following the construction of a canal which was built at the same time as the paving of the main road

tion and her strategies for managing liquid waste:

Selbé (60, woman, Dalifort)

Selbé: Around here we want a sewerage system. That's what we're missing. They promised us that it will be done but we're still waiting. Residents of upstream neighborhoods already have it. For them it was built, but for us, not yet.

[...]

So we dug holes into which we dump our wastewater; the next day, I come with my shovel to remove the sand and I pour some bleach and detergent in the hole to avoid bad smells. The water that's currently left is due to the last rain, but usually it goes away by the evening.

Interviewer: And how do other residents of the neighborhood do?

Selbé: Some of them used to dump here out on the street but many stopped doing so, there are others who are maybe digging holes or something else, but the fact is that waste dumping around here has considerably decreased, so they may have found other alternatives.

In some areas, such as that of Selbé, a sewerage system was not present. In other areas, while a network of drainpipes did exist, some families were not connected to it, usually due to financial reasons:

Aminata (35, woman, Fith Mith)

Aminata: Our gutter is not connected; because we don't have the means to do it. But, there are 3 pits inside the house: when they are full, we dig a hole in the ground where we transfer the water from the pits. Some neighbors' gutters are directly linked to the channel are directly linked to the network, but we don't have the means to pay for the connection... everyone had to pay to get plumbed in, so that the water would get drained directly to the sea.

In the absence of sewerage, different individuals and households had different strategies to cope. And some of these strategies were deemed rather costly measures by those who undertook them, while

others were forbidden or illegal:

Fadima (56, woman, Dalifort)

Interviewer: What about the toilets?

Fadima: We dug holes and placed stones.

Interviewer: Did you dig it outside or inside the house?

Fadima: No, inside, a part of it is reserved for that.

Interviewer: And who uses that toilet?

Fadima: Just us, the family members.

Interviewer: And how do you do when the toilets are full?

Fadima: We call an emptying truck to come and pump them.

Interviewer: How much does it cost you?

Fadima: We haggle, sometimes we can get it for 6000 or 4000 francs.

Interviewer: And how often do you empty the toilet?

Fadima: It can stay for several months before we need a new emptying... 3 to 4 months.

The above interviewee was living in a barrack lent to her and her family for temporary use by the previous mayor of the neighborhood. Having neither running water nor connection to the sewerage system, the family paid for both.

In the same neighborhood, another interviewee described how, following the clogging of a canal in the neighborhood, her family resorted to discharging wastewater in front of the house:

Combé (22, woman, Dalifort)

Interviewer: What do you do with the wastewater after doing the laundry or the dishes?

Combé: We dump it in the canal, not far from here.

Interviewer: The one next to the pharmacy?

Combé: No, not that one. The one next door here... by the way, that canal is no longer operational and it is even forbidden to dump there; people have clogged the network with their garbage.

Interviewer: And what do you do now?

Combé: We pour it out in front of the house.

Indeed, when we visited the canal in question, access to it was

barred by a tall wire net, thus preventing easy access and illegal waste dumping (See Figure 9.1).



Figure 9.1: Barred Canal in Dalifort

Several interviewees admitted to discharging their wastewater in front of their dwelling, thus sometimes in the immediate vicinity of her neighbors with improved sanitation. Their cases illustrate the fact that, in some situations, having the necessary infrastructure is not sufficient to protect the family from coming into contact with liquid waste, if the neighbors don't also have the same amenities.

One aspect which stood out among the problems mentioned was the fact that, when it rained, some people would open their septic tanks so that the rainwater would drain away the contents:

Idrissa (59, man, Dalifort)

Idrissa: Wastewater... you know, we don't have sewerage here. We have only septic tanks; if it's full, we call the truck. There are crooks who discharge it on the road, which is not normal. Personally, I would never do it in my whole life. I don't even have the time and I wouldn't dare to do that.

Interviewer: So there are people who...?

Idrissa: Who throw, yes... during the night, they empty their tanks and throw everything out... that's why the water is a bit dirty.

Interviewer: And they do that next to their houses or do they go a bit further?

Idrissa: No, next to their homes. When it rains, they pour it out... like that, it flows away.

This issue was corroborated later by several other interviewees from Fith Mith, who also attributed the presence of mosquitoes to the stagnant waters generated by this practice. There are, hence, quite solid reasons to believe that this was not a marginal practice among the inhabitants of the neighborhoods located uphill from Fith Mith.

The reason for such a practice is that, as several of the interviewees pointed out, calling an emptying truck to clear out the septic tank comes at a price, while having rainwater evacuate the septic tank is free of charge. The problem, however, with such a practice is that while rainwater mixed with wastewater will flow down from neighborhoods or dwellings located on the top of a slope, the quantity sometimes cannot be contained by evacuation pipes (especially in the absence of good sewerage throughout the whole city), thus causing overspill and stagnation in neighborhoods or dwellings located at the bottom of the slope.

Several interviewees in Fith Mith confirmed the fact that households from neighborhoods uphill open their septic tanks. This exacerbated the problems of wastewater evacuation in the neighborhood, causing floods and water stagnations during the rainy season:

Fatoumatou & Binta, (60 & 24, women, Fith Mith)

Fatoumatou: When it rains... there are some who, in their neighborhoods, discharge their wastewater when it rains. And that gets mixed with rainwater...

Interviewer: And as you're on a low point, it flows down to here?

Fatoumatou: Exactly!

Interviewer: Okay... Madam, you can also join the discussion... so what were you saying about the neighbor-

hood's problems?

Binta: The waters of the septic tanks, the canals can't drain them... the toilets overflow every time and we are tired of it all.

Interviewer: You mean they overflow in the house when the water doesn't get properly drained?

Fatoumatou: Yes, the whole house is full.

Interviewer: And what do you do about that?

Fatoumatou: We manually pump the water out, we take buckets to get the water out.

Binta: Everyone does it and you have nowhere to discharge the water afterwards, it's now forbidden to pour it out in the street.

Fatoumatou: It's now forbidden to pour it out in the streets, to dig holes... all of this is forbidden now.

[...]

Interviewer: Okay... does the neighborhood get flooded when it rains?

Binta: It does, but the water gets drained soon after; when it rains, it's only the septic tanks that cause problems because the water doesn't flow when the pipe is clogged. And so it overflows in the house.

Interviewer: And what's the reason for this?

Binta: The central sewer which leads to the sea gets clogged... even towards the sea, all that area is flooded with sewage water...

The issue was recurrent and each of the interviewees in Fith Mith raised it, adding information which allowed to paint a more comprehensive picture of the situation:

Mame (55, woman, Fith Mith)

Mame: The water coming from the HLM upstream, behind the Technopole, flows down to here and that's why you see these sandbags everywhere erected as protection dikes. The water gets into the houses and even into the rooms. We're on a low point as well, the water from the gutters also spill over: instead of flowing inside the network, they overflow. These sewerage pipes are 0 out of 10.

As soon as it rains only forty millimeters of water, problems arise. The water which should flow inside the normal circuit of the gutters spills out of the toilets of houses and mixes with rainwater. Which floods houses, and then you need to pump the water out. If you came here around 4:00 a.m. when it rains, you'd see quite a movie (laughs). You have to do the chore, otherwise you risk seeing the water besieging your room.

Interviewer: And here, doesn't anyone open their septic tanks when it rains, so that the water drains them?

Mame: No, it would be a disaster in that case... because when it's full, the water overflows. If you open the pits, it would yield even more water!

Interviewer: It's because we were told that some took the opportunity to open their pits when it rains?...

Mame: It's precisely the people of the HLM who do it. We're on a low point and the people of the Cité des Enseignants for example are even lower than us and it's like this all the way to the sea. It's a slope and you would realize what I tell you if you went to that roadway there: it's a basin there... and you would better understand the phenomenon.

Thus, although Fith Mith was entirely covered by a sewerage network in 2015, in practice households often still found themselves experiencing wastewater floods:

Mame (55, woman, Fith Mith)

Mame: Usually in the neighborhood, people dig a hole and pour their wastewater there because sometimes it remains, it doesn't drain. The house is smelly and either you can't get in touch with the ONAS (The National Sanitation Office of Senegal) for an intervention or they give you useless phone numbers and you can't stay too long in that situation.

Interviewer: Is it because the majority of houses have septic fosses inside?

Mame: No, the whole neighborhood has sewerage, everyone is connected to the pipes but they are not operational at all. Sometimes, they can't drain it all. In this case, if you

do not resort to a drain cleaner, you risk seeing wastewater flowing inside your house: the pipes will overflow, you need to act quickly.

On the other hand, two of the neighborhoods, Unité 8 and Soprim 1, were on a slope, which meant that the bottom part of the slope was either at the border or just outside of the neighborhood. As opposed to inhabitants of Dalifort and Fith Mith, those of Unité 8 and Soprim 1 were, by and large, satisfied with the quality of sewerage and they generally did not state having frequent problems with overspill from the evacuation pipes.

In Soprim 1, which is a neighborhood located near a pond (and thus the slope of the neighborhood descends down to the brim of the pond), interviewees seemed particularly content with the quality of wastewater management system in their neighborhood. Here, the interviewees said that they had few issues with wastewater overflowing and whenever such issues did occur, it usually was due to either misuse, which lead to various objects blocking the evacuation pipes. One of the interviewees described such an incident, as well as its cause and the measures needed to solve the issue:

Khadija (19, woman, Soprim 1)

Interviewer: After doing the laundry for example, where do you dump the wastewater?

Khadija: In the shower or we dump it in the pit...

Interviewer: And do they drain in the pit?

Khadija: Yes, they withdraw.

Interviewer: And does it ever happen that the wastewater overflows?

Khadija: When the drain is clogged, yes... but when it's not clogged, it doesn't. Besides, not long ago we had this problem but we unclogged it.

Interviewer: And what do you do when it's clogged?

Khadija: When it's clogged... for example if it rains and the water gets inside, if the drain doesn't work, the house fills with water...

Interviewer: So, rainwater gets into the house?

Khadija: Yes, these last days we had this issue, because the drain was clogged: there was a piece of cloth that blocked

the evacuation... but we removed it.

Another interviewee corroborated these accounts, saying that the neighborhood's drainage system functioned well in general and that when problems occur, it was usually related to blockages and that "if it clogs, it's because of user error or because the person threw things that hinder the evacuation of water" (Niouma (60, woman, Soprim 1)).

Thus, compared to Dalifort and Fith Mith, both Unité 8 and – especially – Soprim 1 seemed to constitute more favorable environments in terms of wastewater drainage¹¹.

Solid Waste

By and large, people seemed to be satisfied with the way solid waste was collected in their neighborhood. Virtually all respondents used the public collection and the vast majority of them said that, although there were days when the garbage truck did not pass, they were generally satisfied with the frequency of passage. However, a few households were slightly less satisfied with the frequency of passage, mentioning strikes as the main reason:

Abdoulaye (62, man, Unité 8)

Interviewer: And is there a truck that collects garbage?

Abdoulaye: Yes. In the morning, it parks here.

Interviewer: Ah, it passes the road here?

Abdoulaye: Yes, over there. There is a bag drop there but you can't leave the garbage here. Early in the morning from 9:30 or 10:00 it passes, if they are not on strike...

Interviewer: And are they often on strike?

Abdoulaye: Ah, yes, often... But not all the time: when there is an issue with wages (laughs). But often, when they don't come, people drop their garbage there, but at night, since it's forbidden to drop it during the day. You can't go and drop your garbage in plain daylight; you wait for nighttime, around midnight, to get it there... but what is missing here are garbage bins, this is the problem in Senegal. Everyone drinks their coffee and throws the cup:

¹¹See Chapter 10 for a more in-depth analysis of the conditions and the levels of residuals in each of these neighborhoods.

plastic waste.

And indeed, aside from strikes by the garbage collection employees, illegal dumping was also a problem mentioned by several interviewees. Thus, it appears that people sometimes dispose of their household garbage either at impromptu dump-sites, in wetlands or in seasonal canals, which are, as already shown, dry except for the rainy season:

Mame (55, woman, Fith Mith)

Mame: You know, behind the HLM, about 200 meters from here is the Technopole: that whole area is a wetland. Well, you pass by there to go to the sea: there is a rubbish dump. The carters come to pick up people's garbage for 100 francs the basin or 50 francs the bucket or 200 francs the bag and then wait for the night to dump them there by the sea. Dead dogs, sheep carcasses, dead cats, garbage, all sorts of things get dumped out there. That is to say that we are landlocked in dirt; between the Technopole and that dumping ground there.

[...] Interviewer: Okay... and does the garbage truck pass to pick up the garbage?

Mame: Yes, it collects garbage, except when they're on strike. During the rainy season, they don't pass regularly because they say that have no passageway due to the stagnant waters; or that their trucks are out of order. And so, it can easily pass a whole week without seeing the garbage truck.

Interviewer: And in this case, how do you manage?

Mame: We put the garbage in bags and store them somewhere until the truck comes.

Interviewer: Does this boost the presence of flies and...?

Mame: Actually, it's more than that... even worms join in.

These are thus some of the several strategies adopted by inhabitants to mitigate for the sometimes irregular passage of garbage trucks. Another interviewee, from Soprim 1, who owned a freezer, said she froze her garbage when cooking, to avoid it decomposing before the passage of the garbage truck. Also from Soprim 1, an interviewee

mentioned that the youngsters of the neighborhood would sometimes dig up a larger hole and ask those with household waste to come and dump it there, to afterwards put soil on top and thus bury it.

Canals

In Dakar, seasonal canals serve to drain excess water from rains during the wet season. These canals are therefore only filled with water around the rainy periods, while being dry for most of the year (Dos Santos, Rautu, et al. 2015). Living in a neighborhood with a seasonal canal, as opposed to a neighborhood without a canal, lead to an increase in the occurrence of febrile episodes in the neighborhood (4) model, but the association lost its statistical significance in model (5), when adding the synthetic indicator on opinion about malaria in the neighborhood.

The association was only significant at a 90% CI, possibly due to the limited number of observations at the last level, of 50 neighborhoods, of which only 2 had seasonal canals. Once the synthetic indicator on the perception of malarial issues in the neighborhood was added, the effect of the seasonality of a canal remained relatively stable, but the variable lost its statistical significance. A possible explanation for this could be that the synthetic indicator on the perceived problem of malaria in the neighborhood is an intermediate variable between the two other ones. Hence, when this synthetic indicator is added to the model, it “draws” part of the association between the seasonality of canals and febrile episodes.

The reason why a seasonal canal was more significantly associated with vector-borne fevers in children, rather than a permanent canal, could be related to behavioral factors. Thus, one of the possible explanations and a hypothesis which we had previously advanced, is that solid waste gets thrown into the canals during the dry period and thus, when heavy rains occur, the canals cannot contain or drain this excess water and therefore overflow (Dos Santos, Rautu, et al. 2015). Conversely, permanent canals are continually draining water throughout the year and, since they are never dry, they would be less prone to being mistakenly used as dumping grounds.

This was thus subsequently investigated in the qualitative component of the research and indeed, several of the interviewees men-

tioned canals that had been clogged by people dumping solid waste inside:

Selbé (60, woman, Dalifort)

Selbé: There was a canal but you know, people don't all function the same way. Some dumped their wastewater with all the trash in it and that ended up blocking the evacuation. If you go there now, you'll see that it's being repaired: because of that it's forbidden to dump anything there.

Perception of malaria in the neighborhood

Lastly, the synthetic indicator relating to the percentage of households which considered that malaria was a problem in their neighborhood, had a strong and significant positive linear association with the odds of children experiencing a vector-related febrile episode. This could indicate that there are aspects or characteristics which are not accounted for by the statistical indicators, but which have an impact on the incidence of water-related febrile illnesses. As the interviews have shown, there are, indeed, aspects at the neighborhood level which are impossible to quantify, such as people from uphill areas who open their septic tanks at rainfall or neighbors who dump their wastewater and solid waste in undesignated areas, which thus become *ad hoc* dumping grounds. Since the addition of this variable alters the effects associated with other variables at the household and neighborhood levels (the impact of bed nets, of the perceived quality of sanitation and of seasonal canals), it seems likely that it constitutes an intermediate variable between environmental factors and the odds of mosquito-borne febrile episodes.

9.5 To Sum Up

Regarding the two binomial models, when successively adding each additional level of analysis, the fixed effects coefficients remained very stable across models. With regard to diarrheal episodes, health literacy, the mother's occupation and amenities in the dwelling seemed to play an important part. Concerning febrile episodes,

anti-mosquito measures seemed to have a counter-intuitive relationship with the odds of disease, leading me to believe a reverse in causality occurs between anti-mosquito measures and the incidence of vector-borne febrile episodes. This prompted further investigation in the qualitative section of the present study, the results of which will be presented in Chapter 11.

Analyzing the interviews conducted in August and September 2015, one of the main findings was that the household and neighborhood level intertwined with regard to provision and perceived quality. Among the three types of provision (access to water, sewerage and solid waste collection) it was wastewater management which seemed to cause most concern to the people interviewed. Moreover, in some neighborhoods, inhabitants of buildings located on or on top of a slope would sometimes open their pits or septic tanks when it rained, so that their contents would spill out and be washed away. This would, in turn, generate overflowing and flooding in areas and buildings located at the bottom of the slope. As was the case in Fith Mith, the people who opened their pits and tanks – thus causing wastewater floods – did not actually live in the same neighborhood as those affected by it. This, as Heller (1999, p. 142) points out, means that only “the population near the dumping ground is exposed to a health risk”. In the case of solid waste, people tend to not throw it in the immediate vicinity of their house. In the case of wastewater, as the interviews showed, it is only those located uphill who open their septic tanks and pits and therefore, the contents spill downward to other areas.

Another aspect which was frequently brought up was that of unsatisfactory quality of provision (overflowing sewers and the erratic frequency of passage of the garbage truck), which lead to illegal dumping and thus mainly affected those living in nearby areas.

Concerning mosquito protection, it seems that, in general, those who use mosquito protection are also those who find that there are relatively many mosquitoes in the area where they live.

Finally, it seems that secondary childcare is more or less commonplace in Dakar. Literature shows that many parents in Dakar externalize childcare and child education and nannies are, at least partially, in charge of coaching the children (Lewandowski 2011). In

poorer households, women help each other care for children or members of the extended family also participate. In wealthier households, a maid may be employed, whose tasks blend housekeeping and childcare.

Chapter 10

The Effect of the Environment

This chapter focuses on the effect of the neighborhood – and, to a lesser extent, the household – in water-related diseases, both in terms of relative impact (compared to the lowest level of analysis : the individual) and in terms of mechanism.

The first part, regarding the relative impact of the household and neighborhood, first focuses on the most commonly used indicators for assessing the relative impact of higher levels in random effect models. Subsequently, it sets forth the steps I followed in choosing the neighborhoods on which to focus. The second part, that of the mechanism in which the neighborhood impacts on individual health, synthesizes information obtained by means of, on the one hand, the community surveys and on the other hand, the interviews and the photographic material adjacent to them.

The community surveys, which were done in the 50 neighborhoods where the main ACTU-PALU survey data had been collected in the second half of 2008, took place during the months of July and August 2009. The interviews and photographs were done in 4 of these 50 neighborhoods, at the end of August and first half of September of 2015. Since the focal point here are the 4 neighborhoods themselves and their specificities, I will be treating each of them separately.

10.1 The Relative Effect of the Higher Levels

One of the key points of interest of the current study is the potential relative role of factors pertaining to the household and the neighborhood, on individual infectious diseases. The starting hypothesis with regard to this aspect is that, albeit smaller than that of the individual level, household and neighborhood levels each bear a significant role in explaining the variability regarding the occurrence of both diarrheal and febrile episodes.

While the true effect of the higher levels (the impact that living in a certain family or area) are unknown, statistical modeling offers estimates of what they may be, taking into account different covariates. Thus, Tables 10.1 and 10.2 present, aside from the number of children, households and neighborhoods considered in each of the models, the variance at the household and neighborhood level (with standard errors in parentheses). It is to be noted that for binomial logit models, variance at the lowest level (which is here the individual one) is often estimated as the variance for the standard logistic distribution, that is $\frac{\pi^2}{3} \approx 3.29$ (Snijders and Bosker 2011) .

Table 10.1: Random Effects for Diarrheal Episodes

	(1)	(2)	(3)	(4)
Random Effects				
Household				
Variance	0.966 (0.102)	0.973 (0.104)	0.939 (0.103)	0.941 (0.103)
ICC	0.23	–	–	–
VPC	0.23	–	–	–
Neighborhood				
Variance	0.033 (0.021)	0.04 (0.023)	0.025 (0.02)	0.024 (0.02)
ICC	0.01	–	–	–
VPC	0.01	–	–	–
Observations				
Children	7311	7280	7280	7280
Households	2949	2945	2945	2945
Neighborhoods	50	50	50	50

In a clustered sample, selecting two individuals from the same group

Table 10.2: Random Effects for Febrile Episodes

	(1)	(2)	(3)	(4)	(5)
Random Effects					
Household					
Variance	0.428 (0.065)	0.45 (0.067)	0.439 (0.066)	0.445 (0.067)	0.447 (0.067)
ICC	0.13	—	—	—	—
VPC	0.11	—	—	—	—
Neighborhood					
Variance	0.061 (0.022)	0.059 (0.022)	0.062 (0.022)	0.044 (0.019)	0.033 (0.016)
ICC	0.02	—	—	—	—
VPC	0.02	—	—	—	—
Observations					
Children	7,323	7,292	7,292	7,292	7,292
Households	2,952	2,948	2,948	2,948	2,948
Neighborhoods	50	50	50	50	50

adds less new information than would a completely independent selection. Using random effects (a multilevel model) tries to mitigate for this association in the structure of the data and, subsequently, to gage its quantity, by estimating how much of the overall variation in the response is explained simply by the grouping structure. Non-continuous response models are not estimated using likelihood methods, hence using likelihood ratio test would be unreliable (Rasbash et al. 2009). A Wald test is only approximate, as variance parameters here are not normally distributed. While the Wald statistic is used for testing the null hypothesis that variance at the higher levels is zero, several indicators are more commonly used to assess the relative effect of the higher levels. Among these, the best known are the ICC, the VPC and the D_{eff} ¹, all of which are generally calculated on the null model (without covariates). Tables 10.1 and 10.2 also present these coefficients for each of the two symptoms investigated.

As far as the occurrence of diarrheal episodes is concerned, Table 10.1 summarizes the four general statistical models: model (1) without any explanatory variable, model (2) adds individual covariates, model (3) also adds variables related to the household,

¹For formulas used to calculate these measures, see Chapter on quantitative methods

whereas model (4) adds variables pertaining to the area. Looking at the null model (1), the between-neighborhood variance, of 0.033, seems low, especially when compared to the within-neighborhood-between-household variance of 0.966 (keeping in mind that the within-household-between-child variance is, in logit models, estimated as equivalent to 3.29).

The neighborhood level ICC expresses the the estimated degree of “similarity” in the outcome variable (diarrheal and febrile episodes, respectively) between two children i and i' within the same neighborhood k , but different households j and j' . The household level ICC expresses the the estimated degree of “similarity” in the outcome variable between two children i and i' within the same household j (and necessarily within the same neighborhood k).

The ICCs for the null model are of 0.01 and 0.23 at the neighborhood and household levels, respectively, while the VPCs have values of 0.01 for the neighborhood and 0.23 for the household. This indicates that while 1% of the variation in diarrheal incidence lies between neighborhoods and 23% lies between households, around 76% of the variation in diarrheal incidence lies between children.

The Wald test posits the null hypothesis that the between-group variance is zero (Leckie 2013). For the neighborhood, the value of the Wald statistic is 2.43, which is compared with a chi-squared distribution on 1 degree of freedom. Since this is smaller than 3.84 – which is the critical value for a test at the 95% confidence level – it is not possible to affirm that there is between-neighborhood variance when it comes to diarrheal diseases. One possible explanation is that generally, the higher the level of analysis, the less impact it has on individual health outcomes (Diez Roux 2001). Another possible reason is the fact that, while each neighborhood has a large sample of households and children, the number of households is relatively low, of only fifty observations. With regard to the household level however, the value is 98.97, which clearly indicates that there is significant variability across households from the same neighborhood. Looking at the neighborhood D_{eff} however, it has a value of 2.12, which indicates that the sample variance is 2.12 times bigger than it would be if the survey were based on the same sample size but with children selected randomly across neighborhoods of the Dakar region and consequently indicates that taking into account

the grouping structure of the data is warranted.

With regard to febrile episodes, the between-neighborhood variance is estimated as 0.061 while the within-neighborhood-between-household variance is estimated as 0.428. The ICC at neighborhood level is 0.02, while at the household level it is 0.13, whereas the VPCs have values of 0.02, 0.11 and 0.87 at the neighborhood, household and individual levels respectively, indicating that 2% of the variation in febrile incidence lies between neighborhoods, 11% lies between households and 87% of the variation in febrile episodes lies between children.

Calculating the Wald statistic, it has a value of 43.73 at the household level and of 7.89 at the neighborhood level, which is compared with a chi-squared distribution on 1 degree of freedom. Bearing in mind that the critical value for a test at the 5% level is 3.84 and 6.64 at the 1%, there is strong evidence that the between-neighborhood variance is non-zero. This is further corroborated by calculating the D_{eff} , which has a value of 3.35, indicating that the sample variance is 3.35 times bigger than it would be if the survey were based on a random sample of equal size.

One aspect to be noted here is that, at the neighborhood level, the inclusion of covariates reduces the residual variability by nearly one third in the case of diarrheal outcomes (from 0.033 to 0.024) and by almost half in the case of febrile outcomes (from 0.061 to 0.033).

The analysis of the random effects suggests that a small proportion of the variation in diarrheal and febrile episodes lies between neighborhoods, significantly more lies between households and most of the variation in the incidence of water-related diseases lies between children. This is not surprising, as “the effects of neighborhoods may also be small in comparison with the individual-level effect” (Diez Roux 2001, p.1787), such as the child’s age or of the mother/carer’s general social status.

10.2 Mechanisms of Impact of the Neighborhood

The process by which living in a certain area influences the risk for infectious diseases was also one of the focal points of this study. Among the 50 neighborhoods of the ACTU-PALU survey, I chose 4 to do a more in-depth documentation, with interviews and photographic material, as well as studying the transcripts of the community surveys done in 2009, as part of the ACTU-PALU project. Here, aspects not yet accounted for, such as general cleanliness of the area (irrespective of household solid waste collection) and potential flooding due to heavy rainfall during the wet season (thus distinct from the household waste water drainage) were at the center-point of the analysis.

10.2.1 The Choice of Neighborhoods

For the choice of neighborhoods to visit, I performed a residual analysis, at the neighborhood level, on the main quantitative models for febrile and diarrheal incidence. Since the statistical analysis yielded estimates of these incidences by neighborhood, comparing them with the observed ones (the data collected) constitutes the basis of residual analysis. Hence, residuals indicate the differences between what one would expect the phenomenon to be and what the phenomenon really is and they give an idea of how far-off from predicting the reality the models were. For this study, I was particularly interested in residuals at the neighborhood level. The areas (neighborhoods) that were furthest from the expectation produced by statistical analysis, were also the most likely to generate compelling qualitative information and thus potentially offer new insights on the relationship between neighborhood and health.

A common way to identify such observations which are less well captured by a model, are residual graphs, also called “caterpillar plots”. In this case, comparing the caterpillar plots for the null model (therefore based solely on the average incidence) versus the full one (which comprises all covariates) at the neighborhood level offered a glimpse into two aspects. Firstly, it gives an estimate of how modeling reduced variability at the highest level. Secondly,

it allowed to draw the two observations most distant from the expectation: the one which had the lowest incidence compared to its predicted value and the one which had the highest one. In all four figures, the horizontal line represents the incidence as predicted by the model. Hence, neighborhoods situated under it have lower-than-expected incidence, while neighborhoods situated above it, have higher-than-expected incidence. Since the residuals are ordered by rank, it becomes thus easy to identify the two neighborhoods which are least well explained by the model, in each of the four figures: they are simply the first and last of the observations plotted.

Regarding diarrheal episodes, Figure 10.1 and Figure 10.2 show the empty and the full/complete models, respectively. The plot also shows the reduction in variability at the neighborhood level, which – given the relatively low variability between neighborhoods – remains rather modest.

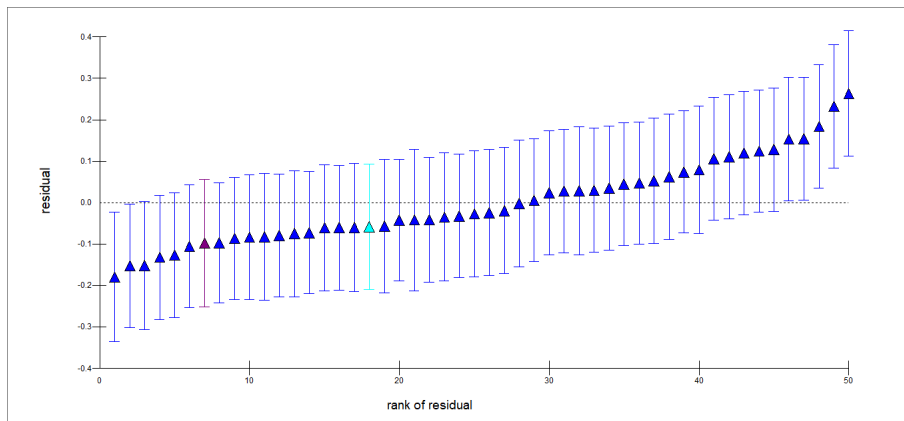


Figure 10.1: Caterpillar Plot for Diarrheal Episodes (Null Model)

For diarrheal episodes, the leftmost observation is the neighborhood of “Soprim 1”, while the rightmost observation is the neighborhood of Fith Mith. This means that, compared to the average of the 50 neighborhoods, Soprim 1 has the lowest incidence of diarrheal episodes, while Fith Mith has the highest. Especially in the case of Fith Mith, its residual variance is particularly important, when compared to that of the other neighborhoods. Subsequently, they are two of the neighborhoods that I selected for investigation.

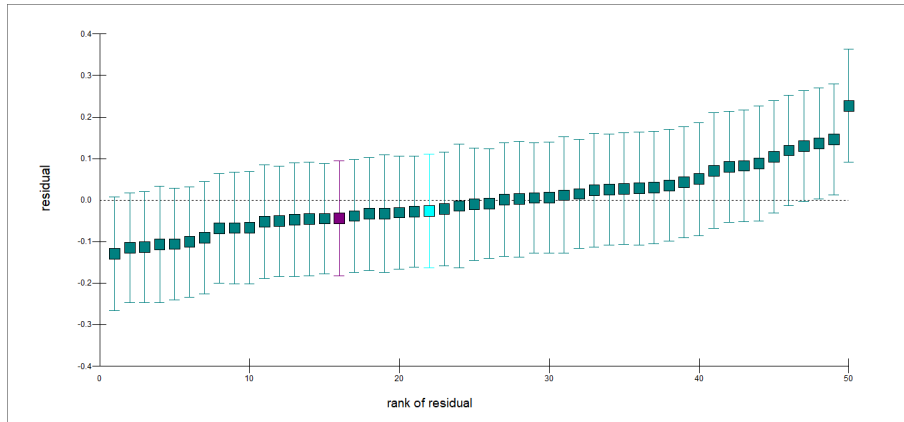


Figure 10.2: Caterpillar Plot for Diarrheal Episodes (Full Model)

One aspect to be noted is that of the two “least explained” neighborhoods for febrile illnesses, which are highlighted in both plot 10.1 and plot 10.2 in light blue and purple. They will be named and discussed in the paragraphs to follow, but what is noteworthy here is that both of these neighborhoods are situated below the prediction line for diarrheal diseases. However, they are situated at opposite ends of the spectrum when it comes to febrile incidence: one of them (highlighted in purple) had higher-than-expected incidence, while the other (highlighted in light blue) had lower-than-expected febrile incidence. The addition of covariates reduced, for both of them, the residual variability (visible in plot 10.2).

Concerning febrile incidence, residual plots (Figures 10.3 and 10.4) show a more substantial reduction in variability at the neighborhood level, in line with fixed effects and with the statistical indicators for random effects at the neighborhood level.

Here too, the two observations least well explained are the ones located leftmost and rightmost on the plots. The leftmost observation is the neighborhood of Unité 8. As Figure 10.3 shows, it has an incidence considerably lower than all other neighborhoods considered in the ACTU-PALU survey and it remains so in the full model. The rightmost observation is Dalifort, which has the highest febrile incidence of the 50 neighborhoods and remains so, even after adding all covariates.

In the caterpillar plots for febrile episodes (Figure 10.3 and plot

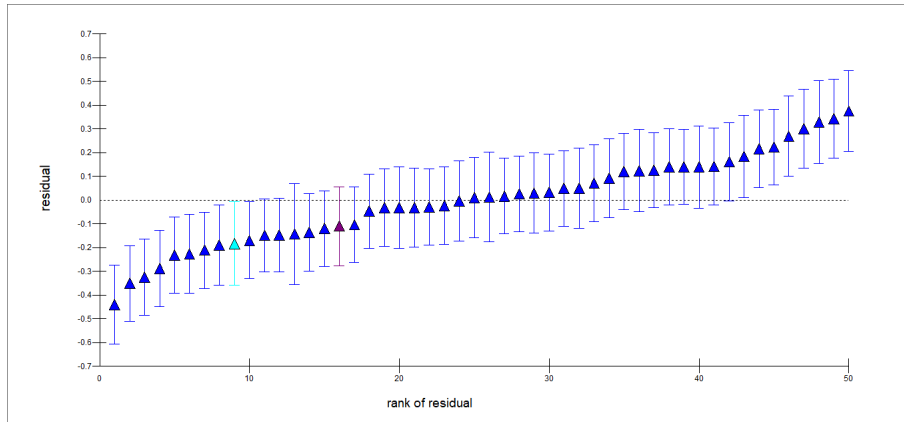


Figure 10.3: Caterpillar Plot for Febrile Episodes (Null Model)

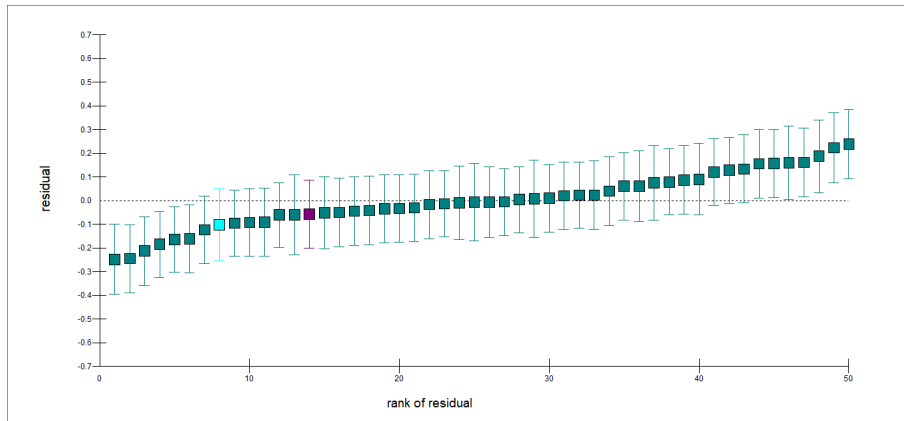


Figure 10.4: Caterpillar Plot for Febrile Episodes (Full Model)

10.4), as was the case with those for diarrheal episodes, I have highlighted the two “least explained” neighborhoods for diarrheal illnesses, which are highlighted in both plots in light blue and purple. These two neighborhoods have already been identified in the caterpillar plots for diarrheal episodes, as Soprim 1 and Fith Mith, respectively. Here too, both of these neighborhoods are situated below the prediction line for febrile diseases, despite being on opposite ends of the spectrum when it comes to diarrheal incidence: Fith Mith (highlighted in purple) had higher-than-expected incidence, while Soprim 1 (highlighted in light blue) had lower-than-expected febrile incidence. Here as well, the addition of covariates reduced, for both of them, the residual variability (visible in plot 10.4).

Thus, it appears that the neighborhood which bears the highest burden in terms of diarrheal diseases is not among those where mosquito-borne febrile incidence is particularly high and viceversa, for the neighborhood which bears the highest burden in terms of mosquito-borne febrile incidence.

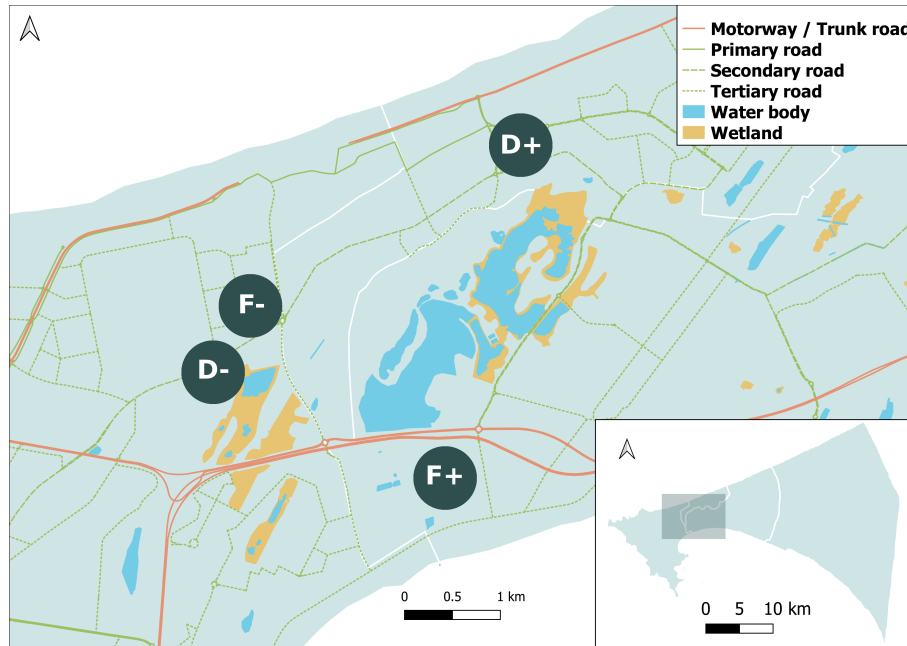


Figure 10.5: The Four Selected Neighborhoods

Map created with QGIS (QGIS Development Team 2019) using OpenStreetMap Foundation 2018 data

Consequently, given the diverse incidence and local features across the 50 neighborhoods of the ACTU-PALU study and the aim to focus on certain more relevant areas, analyzing the caterpillar plots was the basis of choosing which neighborhoods to follow-up on, by means of qualitative analysis. Figure 10.5 pinpoints these four neighborhoods on the general map of Dakar.

The neighborhood on the top right corner is Fith Mith (marked “D+” on the map, it was characterized by high diarrheal incidence) and following clockwise, the one on the bottom right is Dalifort (marked “F+” on the map, it was characterized by high febrile incidence), then Soprim 1 (marked “D-” on the map, it was charac-

terized by low diarrheal incidence) and Unité 8 (marked “F-” on the map, it was characterized by low febrile incidence). As Figure 10.5 shows, these neighborhoods are located in the same general area of the Dakar region, within only a few kilometers of each other, as the crow flies.

Thus, the qualitative analysis at the neighborhood level focused on these four neighborhoods, aiming to identify specificities which could impact on water-related diseases.

High Febrile Incidence: Dalifort

Dalifort is a neighborhood situated in the department of Pikine (one of the regions of the metropolitan area of Dakar), at the border with the Dakar city area and developed along the Route de Rufisque (See Figure 10.5).

The 2009 community survey had five respondents in Dalifort. It revealed that the neighborhood had been built in a tidal flat and that it was fairly recent, as “in any case, people moved in starting from 1992” and that “it was in 1992 that the keys to the houses were given”. In terms of economic status, there were few wealthy people in the neighborhood, while the majority were generally lacking financial means. In 2009, there was a retention basin, built to prevent flooding during the rainy season, but no evacuation canal².

The community survey of Dalifort also revealed an apparently profound dissatisfaction of the respondents with the way floods were managed and the interviewees repeatedly complained about the excess of stagnant water, be it wet or dry season. When asked if the retention basin or water ponds overflow, the respondents expressed their discontent: “absolutely”, “every day”, “all the time” and “there is nothing good here”.

In 2005, a year with major floods, the neighborhood experienced a major exodus, as many people left their houses and “each went to their parents’ until the water had gone down enough to come back”. Similarly, parts of the neighborhood had been flooded in 2008 and some houses remained flooded at the moment of the survey.

²A canal was built a few years afterwards, as mentioned by Selbé in one of the interviews conducted in 2015 and described in Chapter 9

In terms of sanitation, respondents of the community survey estimated that the lack of sewerage was the most important loss in their neighborhood and that, while the people in the neighborhood got along well and had good relationships, “our only problem is grubbiness”, mainly due to stagnant water.

During the 2015 visit for qualitative data collection, Dalifort was probably, judging by the exterior of the vast majority of houses, the least affluent of the four neighborhoods. Except for a few houses (most notably those in the area of the respondent Idrissa), the general built landscape was a mix of wood and metal planks bound together and some concrete buildings, often left unfinished. Many of the streets were littered with left-over construction materials, scrap metal or bags of garbage. Here, compared to the other three neighborhoods, people generally seemed discontent with the level of cleanliness in their area. When asked what she thinks of her neighborhood, if she finds it clean or not, a respondent replied “It’s not clean, it’s dirty ... we even have those things that get into children’s ears, those worms” (Combé, woman, 22). Another respondent, unhappy with the way that authorities managed the issue, took matters into his own hands:

Idrissa (59, man, Dalifort)

Idrissa: To be honest, it’s me who takes care of the cleanliness of the street. It honestly is me who’s taking care of it. I clean, there are people who throw their garbage, bottles, packets. [...] I don’t want people passing by here to throw garbage and then leave. No, I really don’t like dirt.
Interviewer: And if you aren’t there, people throw things?
Idrissa: They throw everything. [...] Maybe it’s passers-by. Sometimes it’s passers-by.

In terms of flooding as well, Dalifort seemed to be affected to a very marked extent and most of the unpaved streets were either scattered with stagnant puddles or downright flooded (Figures 10.6 and 10.7). Some of the streets were difficult to access, since they were covered in water to the whole extent of their width. Examining the water puddles, it appeared they had been there for more than a few days and some of them had larvae swimming inside.

This situation seemed indeed to bother its inhabitants and most



Figure 10.6: Street in Dalifort

respondents from Dalifort strongly complained about it:

Fadima (56, woman, Dalifort)

Fadima: When it rains, we get the water out until it's over.

Interviewer: And since when is it like that?

Fadima: Since a long time ago, we've complained several times but nothing, because this is a tidal flat, that's why. And we don't have enough money to elevate the house.

Interviewer: And when there's a flood, how long does it take for the water to drain?

Fadima: It can go away after 2 days... because we also don't let it stay, we have young children and we want to avoid that they fall into this water.

[...]

Interviewer: You said earlier that you don't let the water



Figure 10.7: Stagnant Water in Dalifort

stagnate in the house for more than 2 days, because of the presence of children, why is it not safe for children?

Fadima: Because of the worms and all... and you can't always watch over young children like that one: he's my grandson. Stagnant water is not good and can transmit diseases.

While people like Fadima remove the water from their houses and yards, in the streets of Dalifort water seemed to have languished a lot longer, becoming stale and foul. In some parts of the neighborhood, the puddles had developed various worms and insects, such as was the case in front of the house of Idrissa (59, man), who said “it’s a real problem here. During the rainy season, I don’t even want people to come see me in this situation, it’s not fair.” (Figure 10.8):

According to one respondent, some inhabitants of the neighborhood had even been forced to vacate their homes and live elsewhere:

Combé (22, woman, Dalifort)

Interviewer: When we entered the house, we noticed a puddle in a corner. Does that often occur here?



Figure 10.8: Flooding in Front of Idrissa's House, Dalifort

Combé: Yes, a lot.

Interviewer: Does it happen every year?

Combé: Since 2010.

Interviewer: And what is causing this situation?

Combé: We were told that this area consisted of a lake some time ago, it was later that people came to build their homes here. That's why, after the rain, the water rises back to the surface. All the houses were affected, ours was flooded. We had to raise it with sand and put tiles, in order to be able to come back to live here.

Interviewer: Are there any houses that are still affected by floods?

Combé: Yes, many. They were even abandoned because of that: this one, that one there and this one too... there are almost 5 houses that were abandoned because of water overflowing.

Interviewer: During this rainy season?

Combé: No, it was during last year's and even that of 2 years ago...

Interviewer: And they still haven't come back?

Combé: No, still not.

Interviewer: And these houses are still under water?

Combé: Yes, up until now they still are.

Out of the four respondents living in Dalifort, one lived in a house on the main road, a road which had been recently paved. She was generally content both with regard to cleanliness and with regard to the rainwater evacuation and said that asphaltting the street had lead to a decrease in flooding in her area:

Selbé (60, female, Dalifort)

Selbé: They have considerably decreased. For those who knew Dalifort in those days and even not so long ago, compared to just a few years ago, it has changed a lot...

Interviewer: And what caused this change?

Selbé: The change... the fact that the roads were asphalted contributed, because there was no [asphalt] at the time... there were dirt roads, which after the rain transformed into muddy tracks. When it rained, the water got into your house [...]. The houses were flooded and we had no pumps or anything... it was only later that we had pumps to evacuate the water when it rained. Also, the asphalt road has been very useful because the water now trickles down to the basin there...

Interviewer: OK, and when were the roads paved? How long ago?

Selbé: The roads... wait, I'll ask my son... he says it's been three years now.

[...]

Interviewer: And when it rains now, does the water stagnate?

Selbé: No, not much. When it rains a lot, there is water up to a certain level, but it drains right after, until there is nothing left.

Thus, in such areas as Dalifort, which are at relatively low elevation,

paving the streets most at risk for flooding may reduce the risks associated with flooding.

High Diarrheal Incidence: Fith Mith

Fith Mith is located in the department of Guediawaye, in the Northern part of the Dakar region, close to the ocean (See Figure 10.5).

The 2009 community survey had five respondents in Fith Mith and it revealed that, although the neighborhood had piped water, its reliability was less than satisfactory, with water cuts happening every less than two months. In 2009, the neighborhood was not connected to the general sewerage system and the respondents singled this aspect out as their main problem in the neighborhood. The neighborhood had low elevation, which, according to the respondents, lead to stagnating water. This, together with a limited amount of wind, was deemed to be the cause of mosquitoes in the area, which arrived, as one of the respondents put it “automatically”.

Walking around Fith Mith in 2015 for qualitative data collection, Dalifort and Fith Mith were in some ways similar, especially with regard to streets. Here too, the buildings, although most of them finished, seemed rather old and unkempt. The streets, although generally dry on the days of our interviews, bore witness to an area which apparently also struggled with floods. Many streets were scattered with various improvised constructions, used to stem the flow of water, such as old tires or sacks of sand (Figures 10.9, 10.10 and 10.11).

Given that Fith Mith was located on a low point of the slope, most of the water would accumulate here, forcing people to construct *ad hoc* dams out of sand bags, so as to keep water from entering their street or their house. Although our visit occurred on a sunny day, these makeshift dams were easy to spot all around the neighborhood, some of them worn out or broken, indicating that they had been in place for a longer period of time. Moreover, although there were considerably less water puddles than in Dalifort and no street was completely submerged, much of the neighborhood was ridden with flies.



Figure 10.9: Street in Fith Mith

Here too, as in Dalifort, houses were often flooded during the rainy season and, in some cases, had to be evacuated:

Safiétou (42, woman, Fith Mith)

Safiétou: There are houses that get flooded, but we evacuate the water manually. We take buckets, we evacuate and it goes away.

Interviewer: You mean, the water gets into the houses when it rains?

Safiétou: Yes...

Interviewer: In your neighbors' houses?

Safiétou: Our neighbors', ours too...

Interviewer: You experienced this yourself?

Safiétou: Yes, of course... our house is at a low point and every time it floods and the water gets into our rooms.

[...]

Safiétou: Houses are flooded. Didn't you see any when you passed?

Interviewer: No... so are there houses with water inside?

Safiétou: Oh yes, there are even some families who've moved because of that.



Figure 10.10: Sand Sacks in Fith Mith

As was the case in Dalifort, one of the respondents from Fith Mith lived in a street that had been paved in recent years. And here too, the person noticed a change in terms of floods:

Aminata (35, woman, Fith Mith)

Aminata: The water gets drained away. Before, the water stagnated but now it drains.

Interviewer: And what made the waters stagnate before?

Aminata: I don't know...

Interviewer: Have there been any works done in the meantime?

Aminata: No, except for the paving of the roads, the gutters to allow for the water to flow.

[...]

Interviewer: And since when have you noticed the difference?

Aminata: Since the paved road was built [...] there is no more water stagnation.

Again, as the interviews in Dalifort also revealed, targeted road paving, in areas most prone to flooding, seemed to alleviate the situation of families living there.



Figure 10.11: Close-up of Sand Sacks

Low Febrile Incidence: Unité 8

Unité 8 is located in the district of Parcelles Assainies, located in the Dakar department. At the junction of two main roadways, the area did not have any water body in its immediate vicinity (See Figure 10.5).

The 2009 community survey in Unité 8 consisted of six respondents and revealed a low to average socio-economic status. Respondents said there were no tidal flats in the neighborhood and only one street had a lower area, but there too “even when it rains, the water disappears after less than 12 hours”. Here, respondents mentioned no sanitation issues (“in fact, there aren’t any real sanitation problems”), except for one: in front of the local dispensary, people tended to dump their garbage sacks, leaving them for when the garbage truck passed. However, when asked if in general, the neighborhood has cleanliness issues, people replied “not really” and

that the whole neighborhood was well served by the piped water and sewerage systems. Thus, in general, the level of satisfaction with existing infrastructures was higher than in the previous two neighborhoods.

Visiting the neighborhood in 2015, at first sight, Unité 8 seemed quite similar to Fith Mith in terms of quality and coverage of street coatings. Looking at the buildings, they were generally one or two storey buildings, maybe slightly better-off than in Fith Mith, but with similarly neglected façades.

However, although the two neighborhoods seemed akin in terms of apparent wealth and road infrastructure, one notable difference was that, while Fith Mith was completely flat, most of Unité 8 consisted of a series of gentle slopes, leading down to the edges of the neighborhood and to the adjoining neighborhoods (See Figures 10.12 and 10.13).



Figure 10.12: Sandy Road in Unité 8



Figure 10.13: Paved Street in Unité 8

One of the interviewees explained that, while their neighborhood was generally safe from floods, the nearby neighborhood of Cambérène (which is located by the ocean) had issues of stagnating rainwater, which sometimes mixed with wastewater:

Adja (26, woman, Unité 8)

Adja: Here [the water] drains, because it's a high point and there's a lot of sand... but it's down there that it stagnates...

Interviewer: So it's there that there are serious problems?

Adja: It's the main road to go to the market and all... and on top of that, wastewater mixes with the puddles.

Interviewer: The market is part of Unité 8?

Adja: No, the market is in Cambérène, at the cross-road.

Walking around the neighborhood, it seemed dry, but for one spot

where we noticed a puddle of water. Seeing a man seated on a bench next to the water puddle, we decided to interview him and he explained that the puddle wasn't due to rainwater, but due to sewerage issues in two nearby houses:

Abdoulaye (62, man, Unité 8)

Abdoulaye: We go around there to go to the mosque, you can't pass there because it's full... it seems that it's the pipe that has issues.

Interviewer: Is that the part of the neighborhood that has the most problems?

Abdoulaye: It's because of the pipe there, it smells...

Interviewer: It's the pipe that...?

Abdoulaye:... smells... sometimes, it gets clogged.

Interviewer: So the pipe gets clogged... and does it overflow?

Abdoulaye: Yes, it does overflow.

[...]

Interviewer: Does the water from other areas flow here or...?

Abdoulaye: No, there are no problems... it's just the pipes of this house there and the one behind...

[...]

E: Ah, okay. And the rest of the neighborhood?

Abdoulaye: The rest of the neighborhood, there isn't any... perhaps in Unité 11, here we're in Unité 8.

In terms of cleanliness none of the interviewees raised any particular concerns, because “the neighborhood is alright... reasonable. It's cleaner than some other neighborhoods anyway”, said Adja (26, woman).

Unité 8 was the first neighborhood where, aside from the elevation, the aspect of landforms was first brought to my attention. While the neighborhood did not seem to differ substantially from the previous one we had visited, that of Fith Mith, people in Unité 8 seemed generally much more content with their environment. The whole neighborhood was on a slope and interviews revealed that, while in their neighborhood water was easily washed away after rain showers, other adjacent areas were not spared by floods.

Low Diarrheal Incidence: Soprim 1

As Unité 8, Soprim 1 is located in the district of Parcelles Assainies, in the Dakar department. Soprim 1 lies to the South West of Unité 8 and the Niayes road, which borders Unité 8 to the south, also borders Soprim 1, but to the North (See Figure 10.5). To the South East, the neighborhood is bordered by a marshland and a pond, but which are not administratively part of the neighborhood.

In Soprim 1, the 2009 community survey was conducted with nine respondents and, with one notable exception, they seemed generally happy with the quality of their environment. The exception was the high presence of mosquitoes, which they attributed to the adjoining wetland and which, according to them, was the source of malarial cases in the area. However, as they all pointed out, although its presence affected them, the wetland did not in fact belong to the neighborhood.

The respondents were content with the sewerage system and they said that the neighborhood is “a sort of slope. If it rains, the water passes quickly” and “disappears entirely after five minutes”. When asked if they experienced floods in the neighborhood, one said “you know, we can’t have floods here. There’s a steep slope around here. Everything flows towards the ravine.”

Another notable aspect, although not directly related to the objectives of the current study, was that while a network of public lighting was in place, it was not functional because “most of the bulbs are not replaced”. Consequently, although the neighborhood officially benefits from such an infrastructure, in fact it does not.

Visiting the neighborhood in 2015, from the exterior appearance of the buildings Soprim 1 seemed – although not a wealthy neighborhood – slightly better-off than the previous three neighborhoods interviewed. In terms of landforms, while Unité 8 was located on rather leisurly slopes, Soprim 1 was crossed by fairly steep slopes, leading down to the aforementioned pond, which was surrounded by a marshland and by an area of abundant vegetation, visible in the background of Figure 10.14).



Figure 10.14: Paved Street in Soprim 1

Aside from the abrupt descent which crossed the entirety of the neighborhood, another aspect which attracted my attention was that here, as can be seen in Figure 10.15, most houses were neither elevated, nor furnished with sand bags around the entrance, as opposed to the numerous makeshift dams of Fith Mith.

In the streets we visited, there didn't appear to be any traces of stagnant water despite the lack of sand sack dams and, most notably, Soprim 1 was the one neighborhood where none of the interviewees complained about floods during the rainy season.



Figure 10.15: Dirt Road in Soprim 1

As several other interviewees, when asked specifically about water drainage, Coura did not mention any malfunctions:

Coura (27, woman, Soprim 1)

Interviewer: What do you think of the neighborhood?

Coura: There are no problems here...

Interviewer: Is there no problem with rainwater, does it drain when it rains?

Coura: Yes, it does drain.

Based on the interviews, Soprim 1 also didn't seem to have any significant issues regarding cleanliness, a situation summed up by one of the interviewees, who said "it's a quiet and clean neighborhood... the only problem are mosquitoes...".

10.3 To Sum Up

In summary, despite the high heterogeneity in incidences observed in descriptive results, the commonly used indicators for random effects, the VPC and ICC suggest there are relatively small neighborhood level differences compared to household and individual ones. This would suggest a rather modest degree of clustering of water-related diseases by area. However, even with this low degree of clustering a multilevel model was significantly preferred to a single-level model (and in the case of febrile episodes, a three-level model was preferred to its two-level counterpart).

The relatively low variance at the neighborhood level, especially for diarrheal episodes, is likely due, in part, to the fact that often the lower levels (such as the individual and their immediate family) which most have an impact on individual health outcomes, as opposed to the higher ones (such as the area of residence). However, given the high heterogeneity in incidence across neighborhoods observed in descriptive results, this may also be due to the relatively small number of observations at the neighborhood level, which impacts on the statistical power at this level.

Community surveys and interviews showed that, in some cases, statistical indicators in such developing-country urban contexts can sometimes be less than reliable and even misleading. Having a certain facility, “on paper”, does not always mean that the inhabitants can actually use it, such as the case was for public lighting in Soprim 1: although electricity was available in their area, since the lightbulbs were not changed, most of the streets were, in fact, unlit.

Secondly, the interviews brought up the aspect of landforms. Firstly, regarding sanitation, living in a flat neighborhood or one that was downhill of a slope put its inhabitants at risk of suffering from the illegal wastewater dumping by their neighbors living in uper-hill neighborhoods. But secondly, the position on the slope is important also because it provides protection during the rainy season for those areas situated uphill and poses an additional risk of flooding for those living downhill. This being said, in these areas situated at relatively lower levels of elevation, additional safety measures such as canals to drain the excess water do seem to

improve the inhabitants' living conditions and satisfaction, as the interviews have shown. Another aspect, somewhat related, is that of targeted road paving, in areas most prone to flooding, which too seemed to lead to a significant improvement, as interviews from both Dalifort and Fith Mith have shown.

Thirdly, the official borders of the neighborhood may not offer an accurate measurement of the environmental factors potentially affecting individual health outcomes. The situation on the field may be somewhat more nuanced than official indicators, since some of the population (most notably that living close to the edges of the neighborhood) may be more affected by the environment in the adjacent neighborhoods. For example, most of the neighborhood of Soprim 1 was strongly affected by the pond and swamp at the bottom of its slope, although the wetland wasn't officially in the neighborhood and therefore was not considered as such, in the statistical analysis.

Consequently, while statistical indicators and modeling offer a good first glance into the relationship between behavior, environment and health, a more qualitative approach is also needed. Directing one's attention also to non measurable aspects, such as people's opinions of their environment, may sometimes offer a better image of their living conditions.

Chapter 11

Interactions

This chapter deals with possible interactions and confounding factors which impact on water-related diseases in children and which I decided to further investigate. On the one hand, I looked more in detail at the possible link between mosquito nuisance in the area and individual or family measures to prevent mosquito bites. On the other hand, I investigated a potential synergistic effect of the socio-economic status and the domestic environment on water-related diseases in children.

11.1 Behavior and Environment: Bed Nets and Mosquitoes

As shown in Chapter 9, general multilevel logistic results show a positive association between using anti-mosquito measures and the risk of a vector-borne fever in children. This, especially in the case of mosquito nets and in light of the extensive literature on the topic, seems a particularly counter-intuitive result. One possible hypothesis as to why the data shows this association, formulated in Chapter 9 is that inhabitants of areas most afflicted by mosquitoes are, by and large, also the ones who are most bothered by mosquitoes. Therefore, they are also the ones more likely to take measures to prevent excessive mosquito bites, especially at night. This situation would lead to a reverse in causality, in that mosquito protection measures would thus be a function of mosquito presence

in the area. Therefore, the presence of mosquitoes would be linked to both the explained (water-related disease) and the explanatory (vector protection) variables, as Figure 11.1 shows.

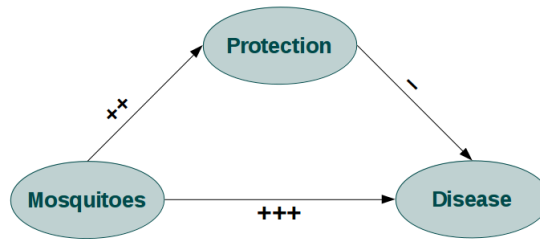


Figure 11.1: Relationship between Anti-mosquito Measures and Mosquito-borne Fevers

In order to further investigate this aspect, I have proceeded to three steps. Firstly, I crossed the question asking households what (if any) mosquito protection measures they used with another question, whereby the respondent gave their opinion regarding whether or not there were few mosquitoes in the neighborhood. Since the respondent had to give their agreement to the affirmation that “There are few mosquitoes in this neighborhood”, agreement with the statement would mean considering that there are few mosquitoes in the area, whereas disagreement would denote that the number of mosquitoes is judged to be high by the respondent.

Although the two questions were not asked to the same person¹, this could provide a first insight into whether the formulated hypothesis is likely to be true or not.

¹The question related to mosquito protection measures was asked to the household respondent, whereas the question related to the perception of mosquito nuisance was asked to one of the mothers/carers in the household.

Table 11.1: Association between perceived presence of mosquitoes and mosquito protection measures

Opinion	Mosquito Protection			Total
	None	At least nets	Other measures	
Disagree that few mosquitoes	49 2.5%	1133 57.87%	776 39.63%	1958 100%
Agree that few mosquitoes	66 6.67%	431 43.58%	492 49.75%	989 100%
Total	115 3.9%	1564 53.07%	1268 43.03%	2947 100%

$$\chi^2 = 70.186, \text{ df} = 2, \text{ p} < 0.000$$

In the contingency table, disagreement with the sentence meant that the woman opposed the assertion there were few mosquitoes in her neighborhood. Thus, 2.5% of mothers/carers who consider there are (relatively) many mosquitoes in the area belong to households where no mosquito protection measure is used. Among women who consider there are few mosquitoes in the area, 6.7% of them belonged to households where no mosquito protection methods are used. The differences are even more striking when looking strictly at mosquito net usage: while almost 58% (57.87%) of women who experienced strong mosquito presence lived in households with nets, only 43.58% of those who experienced limited mosquito presence lived in households with nets.

Thus, it seems that households where there was an opinion that there were few mosquitoes in the area, were less likely to use bed nets as mosquito protection, compared to households where the opinion was that the neighborhood had many mosquitoes.

This relationship was statistically significant, suggesting that there could be a relationship between mosquito presence and mosquito protection measures. This association could interfere in the relationship between mosquito protection measures and febrile episodes. For this reason, I have dedicated a section of each interview to questions on mosquito presence, mosquito repellents and the reasons for use or non-use.

Secondly, I tested two stratified models. The first one was by splitting the sample into two groups: the first group (FEW) consisted of households which considered there were few mosquitoes

in their neighborhood, whereas the second group (MANY) consisted of households which considered their neighborhood had many mosquitoes. Subsequently, I repeated the logistic regression explaining a febrile episode on each of these two sub-samples. Table 11.2 compares the results, regarding mosquito protection measures, of the complete general model, of the complete FEW model and of the complete MANY model:

Table 11.2: Stratified Regressions by Mosquito Nuisance (Odds Ratios)

	General	FEW	MANY
Mosquito protection (none)			
at least nets	1.68**	1.45	2.05**
other measures	1.82***	1.55*	2.23***

Whereas the relationship is maintained across models and the odds of a febrile episode still appear higher among children from households which use mosquito protection measures, the variable has lost part of its statistical significance. And among the households who declare to have few mosquitoes in the neighborhood, using a mosquito net is no longer significantly associated with an increased incidence of febrile episodes in children. This may suggest that at least part of the result regarding mosquito protection obtained in the statistical analysis, can be attributed to mosquito nuisance.

The second stratified model was by splitting the sample by the child's age. I assigned children aged less than five to one group (YOUNGER) and children aged five to ten to a second group (OLDER); subsequently, I performed the logistic regression on each sub-sample. The reasoning behind this was that younger children typically are put to bed earlier and would thus benefit more from the protection offered by bed nets (spending less time outside the bed net, once mosquitoes become active), compared to older children, who tend to stay up after dusk and are thus more at risk, irrespective of whether they sleep under a bed net afterwards. I was hence expecting that, for younger children, the association between bed net use and increased odds for febrile disease lose some of its statistical significance.

Table 11.3: Stratified Regressions by Children's Age (Odds Ratios)

	General	YOUNGER	OLDER
Mosquito protection (none)			
at least nets	1.68**	1.41	1.74**
other measures	1.82***	1.63*	1.84**

Table 11.3 compares results obtained in the general model (comprising indiscriminately children between 2 and 10) with those obtained in the stratified model. As expected, for older children the statistically significant positive relationship between bed nets and odds of vector-borne fevers remains, while for younger children it completely loses its statistical significance. This further suggests that the hypothesis of mosquito protection measures are related to mosquito presence. Hence, since older children would generally stay up later, are more autonomous and spend more time outside, they would be more exposed to mosquito bites before bedtime. A certain loss of statistical significance can also be observed with regard to other anti-mosquito measures.

Thirdly, in the interview structure, I included a section on individuals' perception of mosquito presence in their area and on the potential protection measures they used. Here, the main goal was to test the possibility of reverse causation: that being subjected to more mosquitoes meant, on the one hand, being more exposed to infection and, on the other hand, being more prone to take measures for protection.

In the interviews carried out for this study, it was, indeed, mostly when individuals felt the nuisance of mosquitoes that they were compelled to use bed nets. Usually, the reasons spontaneously given for using a bed net were less the protection it offers against diseases and more the reprieve it provides against mosquito bites and the fact that it allowed for more peaceful sleep:

Fadima (woman, 56, Dalifort)

Interviewer: Are there mosquitoes here?

Fadima: Yes, many!

Interviewer: And what do you think of the situation?

Fadima: Ah, we hang mosquito nets...

[...]

Interviewer: Do you have any family living elsewhere?

Fadima: Yes, I do...

[...]

Interviewer: And when you talk to them, is the area where they live much more infested with mosquitoes or not?

Fadima: No, they even feel sorry for us.

[...]

Interviewer: When do mosquitoes bother you the most, during the day or at night?

Fadima: During the night... If you don't hang the mosquito net, you won't sleep at night... You have to use a mosquito net every night.

[...]

Interviewer: And [...] how do your neighbors do?

Fadima: They too sleep under mosquito nets at night...

Interviewer: And what makes makes it that there's so many of them?

Fadima: In my opinion, I think it's simply because this is a lowland. Here, there used to be only fields before. And where there used to be fields, the humidity level remains very high.

The link between humidity, stagnant waters or wetlands and mosquito presence was also brought up by another interviewee, who also mentioned that mosquitoes start to bite in the early evening, thus long before people go to bed. This limits the efficiency of bed nets, since in the evening most people are still awake and active:

C.N. (woman, 22, Dalifort)

Interviewer: Are there many mosquitoes in the neighborhood?

C.N.: They can even get into your mouth if you open your mouth (laughs)... There's too many of them.

Interviewer: And what causes this situation?

C.N.: It's because of stagnant water in houses, in the abandoned houses.

[...]

Interviewer: And when are there more mosquitoes? Dur-

ing the day or during night?

C.N.: From dusk, there's more and more of them until dawn. Even at 6 a.m., they bite.

Interviewer: And what do you do to protect yourself?

C.N.: We buy mosquito repellents or we use mosquito nets.

Interviewer: Which do you use?

C.N.: Both

Another interviewee in a similar situation explained more in detail why, although bed nets do offer efficient protection from mosquito bites, they cannot be used all the time:

Mame (woman, 55, Fith Mith)

Mame: In Fith-Mith, there are a lot of mosquitoes. Also, our health district does not have the medicine needed to cure diseases which occur with mosquitoes; because there are mosquitoes all year long. You know, back in the day you only saw mosquitoes during the wet season, with grasses and stagnant waters, but now, 365 days a year, there are mosquitoes.

[...]

Interviewer: Okay... and do you use mosquito nets?

Mame: We were given mosquito nets. But you know, when you go out you can not bring them with you. They're only for night-time, you air your room well and then you unfold your mosquito net to sleep

[...]

Interviewer: Okay, and how many mosquito nets did you get for each house?

Mame: For each house, they calculate 2 people per mosquito net... that's how they did.

Interviewer: Okay... and when were these mosquito nets given to you?

Mame: It's been 2 years now. This year and last year too, they did not give any: it was in 2013 that they gave them last time.

Interviewer: And you still use these mosquito nets?

Mame: Oh yes, you're forced to...

Interviewer: Is that because you can not sleep without the mosquito nets?

Mame: Oh no, that's out of the question. Even during the day, if you want to lay down, you unfold a mosquito net; otherwise the flies will give you a hard time... during the night, mosquitoes take over; so you can not do without one.

Bed nets therefore constitute valuable means of protection when the person is lying down at home, but less so when the person is moving or outside of the house. In areas where individuals feel the need to use mosquito nets, they do so during the night, but they cannot use them during the whole period that mosquitoes are active. However, mosquito nets only offer protection if they are properly used and for the whole duration when mosquitoes are prone to seeking bloodmeals, if they are in sufficient number for each member of the household to be protected, intact and properly used (Quive et al. 2015; Yohannes et al. 2000).

Regular ITNs need to be reimpregnated after 2-3 washes, or about every 6-12 months, whereas LLITNs have longer lifespans, which leads to them being widely considered to offer superior protection against mosquito bites, but they too need to be replaced or re-treated regularly, as improper use and frequent washing diminish their effectiveness over time (Shirayama et al. 2007).

However, studies have consistently shown that generally there is significant damage already within one year of use and this increases with duration of use (Quive et al. 2015). One study done in the Lao People's Democratic Republic showed that, while after a 1999-2000 campaign to distribute LLITNs, malaria cases in the district hospital decreased, but rose again a year after the intervention. The researchers found that more than half of nets with holes were not mended and were washed more frequently than recommended (Shirayama et al. 2007).

In the interviews I conducted, several interviewees raised the issue of an unmet need for bed nets. An insufficient number of nets means that "some sleep under a mosquito net, others use mosquito coils" (Safiétou (woman, 42, Fith Mith)). In another household of the same neighborhood, consisting of two families, both with children, only one mosquito net was usable:

Aminata (woman, 35, Fith Mith)

Aminata: Last year or the year before that, I don't remember anymore, we were given mosquito nets when they were making a campaign.

[...]

It's only me who still owns one, those of the others are worn out and unusable...

So, given that in the neighborhoods where people feel there are many mosquitoes, people tend to use more mosquito nets, there seems to be, at least for the people interviewed, an association between mosquito nuisance and bed nets. Moreover, different species of mosquitoes are active at different times: while *Aedes* mosquitoes bite primarily during the day, *Anopheles* species are mosquitoes are generally crepuscular and nocturnal, which means they are active from dusk, throughout the night and until dawn (Centers for Disease Control and Prevention 2010; Centers for Disease Control and Prevention 2012a; Centers for Disease Control and Prevention 2012b). However, both species are vectors for water-related infections. This means that the people living areas with high mosquito density are even more exposed, without being able to fully protect themselves until bed-time. This could, at least in part, explain the significant (and positive) relationship between mosquito protection usage and febrile episodes in children.

While more bed nets are the result of more mosquitoes, the lack of a bed net is also the result of a (perceived) lack of mosquitoes: individuals tended indeed to not use one if they didn't feel the nuisance of mosquitoes:

Abdoulaye (man, 62, Unité 8)

Interviewer: And are there many mosquitoes in the neighborhood or not?

Abdoulaye: No, not really... [...] Me at night, I go to bed like that without anything, I just put on pajamas, but we don't have mosquitoes. They're rare, huh...

One question that was abandoned from the interview was that of asking respondents about the reasons for their use of bed nets, in relation to mosquito-borne diseases, especially malaria. If dis-

ease protection was rarely mentioned spontaneously by individuals, when asked about it most of them tended to give socially desirable answers. Hence, the question was removed after a few interviews.

Thus, it does seem that there is a relationship between the domestic level and the milieu one, in that protection measures (at the household level) are, at least partially, a function of mosquito presence or mosquito nuisance (at the neighborhood level).

This would indicate that mosquito nets may not necessarily offer the expected protection to individuals living in mosquito-prone areas, who are therefore more at risk for mosquito bites. This lack of protection may be due to unmet need, to improper use, to using a mosquito net that's not physically intact or simply due to circadian rhythm, which means that individuals do not go to bed – and therefore do not start using a mosquito net – as soon as mosquitoes become active.

11.2 Socio-economic Status and the Environment

The following pages concern testing the hypothesis that health outcomes – in this case, a water-related disease episode – associated with an unfavorable domestic environment would be to a considerable degree influenced by the mother's/carer's education and, to a somewhat lesser extent, on the family's wealth. The idea behind this is that, given two families with similarly risky environmental living conditions, children whose mother/carer was more educated would benefit from additional measures to protect them, compared to children whose mother/carer was less educated. Moreover, a household with higher financial status could better afford to implement such additional protective measures.

Hence, one of the hypotheses formulated in this study was that water-related disease levels in unimproved domestic environments would be higher when the family is destitute or in a more vulnerable socio-economic situation. Conversely, if the family (specifically the mother or the person who cares for the child on a regular basis) is educated or has an advantageous financial position, the domestic

environment would have a lesser influence on disease, because its effect would be mitigated by the socio-economic status.

In order to test this hypothesis, I have estimated, for each of the two indicators considered (diarrheal and febrile episodes) two additional models, each of them adding an interaction to the full model presented in Chapter 9. Four additional models resulted (See Table 11.4), which I will discuss in the pages to follow.

Table 11.4: Interaction Models on Diarrheal and Febrile Episodes (Odds Ratios)

		<u>Diarrheal episodes</u>		<u>Febrile episodes</u>	
		(1)	(2)	(3)	(4)
Child's sex (male)					
	female	0.97	0.97	1.02	1.02
Child's age		0.84**	0.84**	0.90**	0.90**
Mother's age		1.00	1.00	1.00	1.00
Mother is literate (yes)					
	no	0.83	0.91	0.90	0.86
Mother's occupation (housewife)					
	employed	1.10	1.10	1.11	1.11
	other	1.48**	1.48**	0.95	0.94
Health literacy (high)					
	low	1.25**	1.26**	1.15*	1.15*
Household wealth (high)					
	average	1.24	1.42	1.33*	1.37**
	low	1.58**	1.48*	1.26	1.31
Housing amenities (improved)					
	unimproved	1.1	2.24	1.00	1.15
Mosquito protection (none)					
	at least nets			1.68**	1.68**
	other measures			1.82**	1.82**
Interactions					
	illiterate M/C * unimproved HA	1.19		0.91	
	average HW * unimproved HA		0.46		0.83
	low HW * unimproved HA		0.64		0.82
Sanitation coverage (complete)					
	incomplete	1.08	1.08	0.91	0.91
Sanitation perceived quality (high)					
	low	0.96	0.96	1.19	1.19
Canal (none)					

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Table 11.4 – *Continued from previous page*

	Diarrheal episodes		Febrile episodes	
	(1)	(2)	(3)	(4)
seasonal			1.42	1.41
permanent			1.13	1.12
% perceived malaria issue			2.35**	2.35**
Constant	0.26***	0.23***	0.11***	0.11***
Children	7280	7280	7292	7292
Households	2945	2945	2948	2948
Neighborhoods	50	50	50	50
<i>Note:</i>		*p<0.1; **p<0.05; ***p<0.01		

Models (1) and (2) deal with a diarrheal outcome, whereas models (3) and (4) deal with a febrile outcome. All four models consist of the general full/complete model (with all of the covariates considered for its respective outcome), to which I added two interactions each. In the case of models (1) and (3), it is the interaction between household amenities (HA, which encompass the sanitation and construction of the dwelling) and the mother's/carer's (M / C) ability to read/write, whereas in models (2) and (4) the interaction in question was between household amenities and household wealth (HW)². However, it is to be noted that due to the need to have sufficient observations per category, associated with a multilevel model, the statistical power of the interaction between household wealth and housing amenities may be somewhat reduced. Here, the reference category (that of wealthy households with improved domestic environment) consists of 173 observations, while there are only 17 instances of households in the wealthier category, which have unimproved housing amenities.

Looking at the fixed effects, none of the four interactions are statistically significant. The other, main effects remain very similar between the models with interactions and the general models from Chapter 9. The one notable exception concerns housing amenities (HA), which is also one of the interaction terms in all four models. In all four interaction models, the odds ratios of the main HA effect are markedly different from those in the general models.

²Two additional models, using an interaction between household amenities and health literacy, were also tested

For diarrheal episodes, the odds ratios of belonging to a household with unimproved amenities in the general full model were 1.21. In model (1), which includes an interaction between HA and the mother's/carer's ability to read/write, it drops to 1.1, whereas in model (2), with an interaction between the domestic environment and household wealth, it increases dramatically compared to the general model, reaching 2.24. However, the effect of the housing amenities loses its significance in both of the models which include an interaction for housing amenities. For febrile episodes, the odds ratios are 1.00 and 1.15, compared to 0.95 in the general full model, without any changes regarding statistical significance.

Therefore, starting from these complete models with interactions on housing amenities, the first decision following from the analysis of the fixed effects would be failing to reject the null hypothesis that the effect of the interactions is zero (or that their odds ratio equals one). Following from that would be to adopt the general full models presented in Chapter 9, on the basis of parsimony.

Regarding random effects, adding these interactions also does not yield a noticeable reduction in the residual variance at the household level (the level of the interactions). For diarrheal episodes, it is equal to 0.939 in model (1) and 0.933 in model (2), compared to 0.941 in the main-effects model presented in Chapter 9. For febrile episodes, it is equal to 0.448 in both of the interactions models, compared to 0.447 in the main-effects model³.

In summary, it seems that adding these two interaction terms does not contribute information to understanding the risk factors associated to water-related diseases or the relative role of each level of analysis. Consequently, in line with the conventional Neyman-inspired philosophy of hypothesis testing, it would seem that these data cannot confirm that an interaction exists, between the household environment and socio-economic status, having as outcome water-related diseases in children from Dakar.

³At the neighborhood level, the residual variance is 0.024 and 0.022 in models (1) and (2), compared to 0.024 in the general full model for diarrheal episodes, while for febrile episodes it is 0.033 in both models (3) and (4), the same as in the general full model

Chapter 12

Factors for Co-morbidity

Infectious diseases, along with malnutrition, represent the main burden in terms of public health regarding children from Sub-Saharan Africa (Alicke et al. 2017). In terms of health outcomes, co-morbidity, or the presence of several conditions happening in a more-or-less concurrent manner¹, is generally associated with worse results, increased costs and more difficult management (Valderas et al. 2009).

The current study deals with two conditions, both circumscribed to water-related infections: diarrheal episodes and vector-borne febrile episodes. One of the questions driving the study was related to the factors which determine their co-occurrence and to the factors which impact on one of the symptoms, but not on the other. I was therefore interested in finding out what distinguishes the two conditions and what links them together. In other words, are there factors which influence the occurrence of one type of water-related diseases, but not the other?

This chapter focuses therefore on this question and on a series of multinomial models to explain three states: the occurrence of a diarrheal episode, but not of a febrile episode (“*only diarrhea*” in Table 12.1), the occurrence of a febrile episode, but not of a diarrheal episode (“*only fever*” in Table 12.1) and the occurrence of both

¹The diseases can either be both present at the same time or occur within a given period of time, albeit not being both present at the same time

diarrheal and febrile episodes during the reference period (“*both*” in Table 12.1).

The number of children having experienced only a diarrheal episode was 701, those having experienced only a febrile episode were 1291 in number, while 450 experienced both and 4865 had neither symptom. The pages to follow present the results from three models: model (1) includes no covariates², model (2) includes all covariates common to both symptoms³, whereas model (3) adds variables specific to febrile episodes (the presence of a canal in the neighborhood, mosquito protection measures used in the household and the percentage of households who consider that malaria is an issue in their neighborhood)⁴.

12.1 Fixed Effects

Table 12.1 presents the odds ratios for each of the two symptoms analyzed exclusively, as well as for the occurrence of both symptoms during the reference period. Generally, the effects follow the direction of those seen in the general logistic models (see Chapter 9), with a few notable differences which will be discussed in the pages to follow.

Table 12.1: Multinomial Models for Symptom Co-occurrence (Odds Ratios)

		Symptom	(2)	(3)
Child’s sex (male)	female	<i>only diarrhea</i>	0.88	0.88
		<i>only fever</i>	0.96	0.96
		<i>both</i>	1.09	1.09
Child’s age		<i>only diarrhea</i>	0.84***	0.84***
		<i>only fever</i>	0.90***	0.90***
		<i>both</i>	0.81***	0.81***
Mother’s age		<i>only diarrhea</i>	1.01	1.01
		<i>only fever</i>	1.00	1.00

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²As done previously in this study, the null model is only presented in Table 12.2, which deals with the random effects of these multinomial models

³Model (2) thus is the same as the full model for diarrheal episodes in the logistic models (see Chapters 6 and 9)

⁴Model (3) is thus equivalent to the complete model for febrile episodes in the logistic models (see Chapter 9)

Table 12.1 – *Continued from previous page*

		Symptom	(2)	(3)
		<i>both</i>	1.00	1.00
Mother is literate (yes)				
	no	<i>only diarrhea</i>	0.95	0.95
		<i>only fever</i>	0.86*	0.86*
		<i>both</i>	0.79	0.80
Mother's occupation (housewife)				
	employed	<i>only diarrhea</i>	1.08	1.08
		<i>only fever</i>	1.09	1.09
		<i>both</i>	1.19	1.21
	other	<i>only diarrhea</i>	1.61**	1.59**
		<i>only fever</i>	0.91	0.90
		<i>both</i>	1.45	1.43
Household wealth (high)				
	average	<i>only diarrhea</i>	0.87	0.88
		<i>only fever</i>	1.15	1.14
		<i>both</i>	2.15**	2.19**
	low	<i>only diarrhea</i>	1.22	1.24
		<i>only fever</i>	1.09	1.08
		<i>both</i>	2.46***	2.52***
Health literacy (high)				
	low	<i>only diarrhea</i>	1.32**	1.34**
		<i>only fever</i>	1.18**	1.19**
		<i>both</i>	1.24*	1.26*
Mosquito protection (none)				
	at least nets	<i>only diarrhea</i>		1.24
		<i>only fever</i>		1.55**
		<i>both</i>		2.25**
	other measures	<i>only diarrhea</i>		1.17
		<i>only fever</i>		1.72**
		<i>both</i>		2.30**
Housing amenities (improved)				
	unimproved	<i>only diarrhea</i>	1.17	1.20
		<i>only fever</i>	0.94	0.92
		<i>both</i>	1.14	1.13
Sanitation coverage) (complete)				
	incomplete	<i>only diarrhea</i>	1.12	1.10
		<i>only fever</i>	0.85	0.88
		<i>both</i>	0.96	1.03
Sanitation perceived quality (high)				
	low	<i>only diarrhea</i>	1.00	1.02
		<i>only fever</i>	1.39***	1.29***
		<i>both</i>	1.06	1.00
Canal (none)				
	seasonal	<i>only diarrhea</i>		1.24
		<i>only fever</i>		1.34
		<i>both</i>		1.79*
	permanent	<i>only diarrhea</i>		0.91
		<i>only fever</i>		1.11

Continued on next page

Table 12.1 – *Continued from previous page*

	Symptom	(2)	(3)
	<i>both</i>		1.15
% perceived malaria issue	<i>only diarrhea</i>		0.53
	<i>only fever</i>		2.41**
	<i>both</i>		1.80
Constant	<i>only diarrhea</i>	0.23***	0.32**
	<i>only fever</i>	0.36***	0.11***
	<i>both</i>	0.11***	0.03***
Children	<i>only diarrhea</i>	5539	5539
	<i>only fever</i>	6126	6126
	<i>both</i>	5289	5289
Households	<i>only diarrhea</i>	2535	2535
	<i>only fever</i>	2693	2693
	<i>both</i>	2497	2497
Neighborhoods	<i>only diarrhea</i>	50	50
	<i>only fever</i>	50	50
	<i>both</i>	50	50
<i>Note:</i>		*p<0.1; **p<0.05; ***p<0.01	

12.1.1 Demographic factors

For all of the three demographic factors considered – the child’s sex, the child’s age and the mother’s/carer’s age – multinomial results confirmed what the logistic models presented in Chapter 9 did. Neither the child’s sex nor the carer’s age had an impact on the odds of either condition, and nor did they have an impact on the odds of experiencing both conditions. Given the large sample size at this level, it is probably safe to assume that neither of the two aspects has a notable impact on childhood water-related diseases.

Contrarily, the age of the child remained a statistically significant factor, with each additional year of age lowering the odds of diarrheas only by 16% and of fevers only by 10%. Moreover, age seemed to have a synergistic impact on the odds of experiencing both a diarrheal and a febrile episode, lowering the odds by almost 20% with each year of life.

12.1.2 Socio-economic factors

The mother/carer being able to read/write only had a significant impact on febrile episodes alone, where having an illiterate mother was associated with a 14% (significant at a 90% confidence interval)

reduction in the odds of a febrile episode having been reported in the child⁵. Contrarily, on diarrheal episodes alone, its odds ratio were close to one (0.95 and not statistically significant). This appears to confirm the hypothesis formulated in Chapter 9, of differing propensities to report a disease in children (Filmer 2005). Fever is a less easily observable symptom than diarrhea in a child, so it is likely that mothers who are less educated would thus tend to less often notice their children's fever, since it demands a more attentive and somewhat medically trained eye. And since the symptoms in children were declared by the family and not observed by the interviewer, under-declaring fevers by illiterate mothers may well lead to apparently lower odds for children whose mothers/carers are illiterate. Therefore, these results suggest that the hypothesis of a reporting bias concerning illiterate mothers/carers is true.

Again, the mother/carer being employed did not lead to a statistically significant increase in the odds of disease for the child, compared to stay-at-home mothers/carers. However, the "other" occupational status remained statistically significant, but only for diarrheal diseases alone, where it lead to an increase of around 60% in odds. Again, this seems to confirm the hypothesis that this category may in fact express women with a higher level of deprivation, since the "other" category consists mainly of women who are students, apprentices or women who do odd jobs or are household aids. In this light, it would be understandable that this category has more impact on diarrheal episodes than on febrile episodes alone or on both conditions, as the mother/carer can do more to prevent exposure to diarrhea, than to prevent exposure to vector-borne fevers (which would mean to prevent the access of mosquitoes).

The effect of the household's wealth category follows the expected pattern, in the sense that belonging to a household with average or low income is associated with a large and significant increase in the odds of both types of water-related diseases (2.15/2.19 for an average income and 2.46/2.52 for a low income). Therefore, household wealth has an indiscriminate effect on both symptoms, but it does not appear to have a significant specific effect on either exclusively febrile or exclusively diarrheal episodes. This is not

⁵This, as discussed in Chapter 9, could seem counter-intuitive, as maternal education generally constitutes a protective factor in terms of child health.

surprising, given existing literature on the topic, where household wealth has an impact on most health outcomes, with increased risks for children from less privileged families (Mosley and Chen 1984; Palloni 2006).

12.1.3 Behavioral factors

As in the logistic models, the role of behavioral factors remains notable. Health literacy has an effect on water-related diseases when looking at both of symptoms, with lower health literacy being associated with an approximately a one-quarter increase in the odds of developing both symptoms. However, it also has a specific impact for diarrheal diseases alone and a specific effect for febrile diseases alone. Comparing the three models, the impact of a low level of health literacy seems to be the strongest on diarrheal episodes (where it leads to an approximately one third increase in the odds of disease) and the lowest on febrile episodes (leading to an increase of 18%-19%).

With regard to anti-mosquito protection, unsurprisingly neither the use of nets, nor the use of other measures has a significant impact on diarrheal episodes. On febrile episodes considered exclusively, the effect of anti-mosquito protection remains in the same direction as in the general logistic models.

However, when looking at both symptoms taken together, anti-mosquito protection measures have a strong and significant impact, being associated with more than doubling the odds of experiencing both a febrile and a diarrheal episode. The most likely reason for this was given by several of the interviewees, who revealed that most often, where there were mosquitoes, there were flies as well: “if you see mosquitoes somewhere, you’ll necessarily also see flies; they go hand in hand.” (Niouma, 60, Soprim 1). Most participants spontaneously associated the presence of flies with that of mosquitoes: “there are many mosquitoes, but also flies... we don’t know what to do about this anymore” (Mame, 55, Fith Mith).

Participants also made a direct link between the rainy season, with the floodings and additional humidity around dumping sites it yielded, and the presence of both flies and mosquitoes in their area: “they [the mosquitoes] are more numerous during the rainy

season... as are flies [...] during the wet season there are many flies and mosquitoes” (Fatoumatou, 60, Fith Mith), their cause being “humidity, water stagnations because if you pump, the flies go away” (Safiétou, 42, Fith Mith).

This brings back up the topic of nuisance, which influences both protection measures and the risk of disease (due to increased exposure) and can explain why the variable has a significant impact on “fever only” and on “both symptoms” but not on “diarrhea only”.

12.1.4 Environmental factors

Household environmental factors, while statistically significant for diarrheal episodes in the logistic models, have lost their significance when studying only diarrheal episodes exclusively and ruling out the occurrence of a febrile episode as well. Neighborhood sanitary infrastructure again seemed to not have a significant impact, as in the logistic models. However, while the coverage of aforementioned equipments did not have a significant impact, their quality (at least inasmuch as judged by inhabitants of the neighborhood), did, but only on febrile episodes (a result that had been suggested also by the logistic models). Despite the small sample size at the neighborhood level, the effect is significant at a 99% confidence interval. Its size is a 39% increase in odds (in model (2)), which drops to 29% when the synthetic indicator on the perceived burden of malaria in the area is included (in model (3)). Thus, children living in neighborhoods with poor perceived sanitary infrastructures have odds almost 40% and 30% higher of a febrile episode (compared to their counterparts from neighborhoods where the perceived quality of the sanitary infrastructures is better). Here too, an interesting finding is that the synthetic indicator related to individuals’ perception of malaria in their neighborhood seemed to be associated with (and thus “take on” part of the effect of) the quality of sanitary equipments in the area.

In Dakar, seasonal canals serve the purpose of evacuating excess rain water during the wet season, being thus dry for the most part of the year. Having a seasonal canal in the area (as opposed to none) seemed to impact both symptoms, leading to an increase

of almost 80% in the odds of experiencing both a febrile and a diarrheal episode. This, as explained in Chapter 10, is most likely due to the fact that seasonal canals tend to get clogged up with solid waste during the dry season, which leads to overflowing during the rainy season. Therefore, having seasonal canals in the neighborhood is likely to constitute a sanitation issue.

Finally, the synthetic indicator regarding the perception that malaria represents a public health problem in the area has an impact only on febrile episodes exclusively, which is what was to be expected. Its impact is statistically significant and relatively large in size, being associated with a more than twofold increase in the odds of having experienced a febrile episode.

12.2 Random Effects

Table 12.2 presents the random effects for the null model, as well as indicators allowing to estimate the relative role of each of the two higher-order levels (household and neighborhood).

Table 12.2: Random Effects for the Multinomial Null Models

	Only diarrhea	Only fever	Both
Random Effects			
Household			
Variance	1.063 (0.141)	0.427 (0.078)	1.473 (0.201)
ICC	0.26	0.13	0.31
VPC	0.24	0.11	0.31
Neighborhood			
Variance	0.100 (0.042)	0.077 (0.027)	0.001 (0.031)
ICC	0.02	0.02	0.00
VPC	0.02	0.02	0.00
Observations			
Children	5566	6156	5315
Households	2541	2698	2503
Neighborhoods	50	50	50

At the household level, the within-neighborhood-between-household variance is 1.063, 0.427 and 1.473 for diarrheal only, febrile only and both diarrheal and febrile episodes respectively.

The ICCs for the null model are of 0.26 for children having experienced solely diarrheal episodes, 0.13 for those having experienced solely febrile episodes and 0.31 for those having experienced both. The VPCs, which are equal or smaller in value than the ICCs (due to equal or smaller numerators), are of 0.24, 0.11 and 0.31, respectively, indicating that 24% of the variability in experiencing only a diarrheal episode, 11% in experiencing only a febrile one and 31% in experiencing both lies at the family and dwelling level. Experiencing only a febrile episode seems to be the least influenced by the household level, whereas experiencing both a febrile and a diarrheal episode seems to be the most influenced by it. For all three categories of symptoms, the Wald statistic⁶ indicates that there is significant variability across households from the same neighborhood, with values of 56.91, 30.27 and 53.55 for only diarrheas, only fevers and both symptoms respectively.

At the highest level of analysis (here, the neighborhood), the ICCs and the VPCs have the same value, which is 0.02, 0.02 and 0 for diarrheal episodes alone, febrile episodes alone and both diarrheal and febrile episodes. This translates into 2% of the variation in either diarrheal incidence alone or febrile incidence alone being explained by belonging to a neighborhood. However, when both symptoms are taken together (in the “both”) model, the grouping structure at the neighborhood level doesn’t seem to explain any of the variance in the incidence of both diarrheal and febrile episodes jointly.

Moreover, calculating the neighborhood D_{eff} , it has values of 3.48 for each of the two symptoms treated singly, but of 1.022 for the occurrence of both types of water-related infections. This means that, when looking at the incidence of either diarrheal episodes or febrile episodes (but not both), the sample variance is almost 3.5 times larger than it would be if the survey were based on an equally-sized random sample of children, across neighborhoods of the Dakar region. But, when looking at the occurrence of both symptoms, the grouping structure does not lead to a significant increase in the sample variance, compared to a random one of the same size. This is consistent with the caterpillar plots representing the residual variance at the neighborhood level. Thus, Figures 10.1, 10.2, 10.3 and 10.4 had suggested that the neighborhood which bears the high-

⁶To be compared with a chi-squared distribution on 1 degree of freedom

est burden in terms of diarrheal diseases is not among those where mosquito-borne febrile incidence is particularly high and viceversa, for the neighborhood which bears the highest burden in terms of mosquito-borne febrile incidence. This is potentially related to the fact that, although many of the risk factors appear to be similar, the pathways for transmission are different between the two types of infection and the category “both” may thus express several different pathologies of different types, rather than two symptoms of the same pathologies.

The Wald statistic – which compares the results to the null hypothesis that there is no variance between groups – leads to similar conclusions. Its value (which is to be compared with a chi-squared distribution with one degree of freedom) is of 5.696 for diarrheal episodes solely, 7.927 for febrile episodes solely and 0.002 for diarrheal and febrile episodes taken collectively. Compared to its critical value of 3.841 at the 95% confidence interval, it leads to the conclusion that there is strong evidence that the between-neighborhood variance is non-zero, which thus applies to the occurrence of each of the two symptoms taken separately, but not to both symptoms concurrently.

The random effects of the multinomial models clearly indicate that the neighborhood has, separately, an effect on diarrheal episodes just as well as on febrile ones and thus suggests that taking into account the grouping structure of the data is warranted. However, when diarrheal and febrile episodes are analyzed together, the effect of the neighborhood seems to disappear. This would translate into saying that a child is not more at risk of having both conditions, based solely on the child’s living in a specific neighborhood; that, in turn, could suggest that there are different mechanisms of action between the two types of symptoms. However, a more likely reason for this finding is the low overall number of cases – 450 children – who have experienced both a diarrheal and a febrile episode. This translates to an overall incidence (across all 50 neighborhoods) of only 6%, leading to particularly low incidences per neighborhood: almost a third (15 neighborhoods) under 5% and all neighborhoods under 13%.

12.3 To Sum Up

Generally, the fixed effects in the multinomial models follow the pattern of the logistic models presented previously in this study, which corroborates the conclusions drawn and confirms their stability. However, since the multinomial models deal with each symptom separating it and excluding the other, some differences provided additional insights into the web of determinants for water-related diseases.

A notable finding is that behavioral factors (and health literacy in particular) have, aside from their impact on the odds of developing both symptoms, a specific effect associated with each symptom, which underlines their potential in shifting the health status of children from risk-prone areas.

As in the logistic models, the coverage of sanitary infrastructures did not have a significant impact on water-related diseases and this, aside from the small sample size at the neighborhood level, may well be due to the unreliability of indicators pertaining to coverage. As the interviews and the community survey have shown, in several cases, while the infrastructure was present, it was either malfunctioning or just broken, which made coverage a poor reflection of reality. Contrarily, the perceived quality of these infrastructures increased in statistical power regarding febrile episodes, which also seems to draw attention upon the necessity to not only measure the availability of a specific infrastructure, but also its functioning state at the moment of inquiry and its quality, as experienced by those it serves.

When adding the synthetic indicator on the perceived prevalence of malaria in the area, both the presence of a seasonal canal and the usage of anti-mosquito measures (other than nets) lost some of their statistical power. One possible hypothesis regarding this would be that perceived malaria in the area may be related to the “sanitary perceived quality” and to the “seasonal canal” indicators, and hence, adding the synthetic indicator on perceived issues with malaria in the area would draw from their effect.

The random effects confirmed the necessity to take into account both the household and the neighborhood levels when studying

water-related diseases, since both the family/dwelling-grouping and the area-grouping had an impact on each of the two symptoms taken separately. However, when taken conjointly, the area appeared to lose its effect. This could be due to several factors. On the one hand, it could potentially indicate that different mechanisms of action come into play in the relationship between the neighborhood and each of the two conditions. These differing pathways might favor one type of infection, but not the other and hence mask each other when fevers and diarrheas are treated in conjunction. This situation would therefore prompt the justification for the two symptoms to be treated separately. On the other hand, in a multilevel model, the low number of cases who experienced both symptoms is likely to considerably limit the statistical power at higher levels.

Part V

DISCUSSION AND CONCLUSIONS

Chapter 13

Discussion

The following pages examine the chief results of the current research and the ensuing chapter is divided into two sections. Firstly, I will review the main findings in the context of the existing literature on the topic of water-related diseases in children. Subsequently, I will lay out the main strengths of the research, its limitations and some measures I undertook in order to mitigate them.

13.1 Relation to Existing Literature

13.1.1 Demographic Factors

With regard to the child's characteristics, the results obtained in this study show that, while sex doesn't play a significant role in the propensity for contracting a water-related disease, age does. Thus, the older the child, the less at risk they are to both vector-borne fevers and diarrheal diseases and this confirms results generally found in the literature on the topic.

With regard to the child's sex, from a biological standpoint, a trade-off in terms of immunologic response to pathogens has been observed. Thus, boys tend to have a slightly higher vulnerability when faced with some pathogens, partly due to a stronger immune response in girls. On the other hand however, girls tend to also exhibit higher levels of proinflammatory immunitary responses, which tends to predispose them to increased immunopathology (Muench-

hoff and Goulder 2014). Hence, the vast majority of research dealing with water-related diseases in children tends to agree that no significantly different patterns of infection occur across the two sexes.

This protective role of age is most likely due to the fact that, in the first years after birth, striking a balance between immunotolerance and immunoreactivity makes for a relatively lengthy maturation of the immune system. This, in turn, makes children more vulnerable to pathogens in early life (Muenchhoff and Goulder 2014). In terms of exposure, the patterns are also different across ages. While for school-age children, being in the company of peers may add to the risk of infectious disease transmission, for younger children the additional exposure, especially to diarrheal pathogens, comes from increased mouthing, crawling and playing in or close to the ground (Shope 2014).

However, it can also be argued that, since both diarrheal and febrile episodes were recorded on the basis of declaration (by an adult), for older children, a higher proportion of episodes, maybe the less acute ones, could be overlooked. In other words, that parents are likely to better notice a diarrhea or a fever in a younger child than in an older one, especially when it comes to less acute episodes. Hence, according to this hypothesis, part of the reduction in diarrheal and febrile episodes associated with age would, in fact, be attributed to under-recording. From this perspective though, while it is easy to imagine this under-recording happening for febrile and for diarrheal episodes, there is little reason to imagine it would lead to the under-recording of the co-occurrence of these symptoms, in a manner separate from that of each symptom. However, in the present research, age not only had a protective role for each of the two symptoms studied, but it also had a synergistic effect on the odds of experiencing both diarrheal and febrile episodes. This suggests that age does, in itself, have a true protective role on water-related disease outcomes. Also analyzing co-occurrence of diseases and using DHS data from 2005-2006 in India, Yadav (2017) also found that age had a synergistic effect on the relative odds of contracting both diarrheal and febrile episodes. Using age groups (with 0 to 5 months as reference category), the authors found a sharp increase in the relative odds ratio for children aged 6 to 11 months, followed

by a steady decline up to 59 months.

This initial increase, followed by a decrease in risk is similar to the results obtained by Kandala and colleagues (2009; 2007; 2006) in Malawi, Nigeria and Democratic Republic of Congo and could be due to the fact that usually, by 6 months, babies are no longer exclusively breastfed (solid food is introduced in the diet), which reduces the protective role of breastfeeding and exposes them to additional pathogens. This occurs while the infant is still very vulnerable to pathogens, due to an immature immune system. However, due to data availability, all of the four studies were limited to children aged less than five.

Aside from this, the regressions stratified by age category which were presented in Chapter 11 showed that the patterns of relationship between anti-mosquito measures and the occurrence of febrile episodes in children are different for younger and for older children. Given the underlying hypothesis, that anti-mosquito measures are to a large extent a function of mosquito nuisance and thus of (perceived) mosquito presence, this implies that additional attention needs to be directed towards studying possible ways of protecting older children, who are more likely to stay awake at hours when mosquitoes bite.

Aside from the child's age, the mother's age is sometimes considered as a determinant of child health, in that having a teenage or a very young mother may negatively influence the child's health. On the one hand, there are biological factors regarding the mother's age at birth, as very young mothers may be more at risk for a too low BMI, as well as for inadequate weight gain during pregnancy. On the other hand, there are social factors, in that young mothers usually tend to be more socio-economically disadvantaged, less health-conscious or less likely to seek healthcare services (The World Bank, 2000, cited by Finlay et al. 2011; Kandala, Magadi, et al. 2006).

In the current study, data concerning the mother's age at the birth of child's was not available, since it was the primary female carer who was documented and this may not always be the child's biological mother. This being said, when looking at the mother's/carer's age, it did not have a significant effect on either of the two symp-

toms considered¹. On the one hand, both behavioral factors and socio-economic factors have been introduced in the multivariate models, which limits their mediating effect on child health. On the other hand, very few of the primary carers in this study were under 20 at the time of the survey, with only 50 women, out of 4024, aged under 20 (and 29 of these women were aged 19).

13.1.2 Socio-economic Factors

Generally, the mother's/carer's education is considered to be a protective factor against infectious diseases in children and this relationship is primarily mediated by more health-conscious behaviors and health service use in mothers/primary carers who are educated² (Noor et al. 2006).

Only 105 (or 2.6%) of the mothers/carers in the ACTU-PALU sample had reached higher education, while over 40% (1654) had no formal education. Due to this general low level of education of the primary carers in the sample, I chose to use the ability of the child's primary carer to read/write as a proxy for the mother's/carer's education³.

Another reason for this choice was that while for the most part successful completion of a formal education cycle leads to literacy, in some cases education may not reflect the person's current status: some women having completed a cycle of schooling may not necessarily be able to read/write or they may have learned it, but lost the skill over the years. Conversely, in other cases, the women may have learned to read and write either in private or by participating in literacy programs for adults.

Having a primary carer who can read/write had no significant impact on diarrheal episodes or on the odds of experiencing both

¹A potential non-linear effect of the mother's age was also tested, in two manners: firstly, by adding the mother's age squared as a covariate and secondly, by using age categories instead of years of age.

²In this study, there was a statistically significant positive association between literate primary carers and adopting protective health behaviors in the household (results not shown).

³Using formal education, rather than being able to read/write, has also been tested, using three categories: none, primary and "secondary and above", with similar results.

symptoms (a diarrheal, as well as a febrile episode). Regarding vector-borne febrile episodes, having a literate mother/carer was associated with higher odds for the child to have been declared ill. Despite the widely-recognized role of parental education on child health, several studies have reported the absence of a statistically significant relationship between the two aspects, a situation which is often attributed to several factors.

On the one hand, when disease in children is reported by the carer, differing propensities to notice (and therefore to report) the disease, may lead to bias (Filmer 2005). Hence, when data concerning the occurrence of water-related disease symptoms is collected on account of declaration from the respondent, the relationship between education in general and education regarding health may result in different propensities to notice/report disease, with under-declaration on behalf of less educated mothers/carers. In the current study, the fact that having a literate primary carer has a statistically significant positive association with the odds of fever, but not of diarrhea tends to support this hypothesis, since fevers are often less easy to spot than diarrheas and may more easily be overlooked by less trained carers.

On the other hand, especially in Sub-Saharan Africa, specific conditions may result in weaker effects of the mother's education: practices such as child fostering and extended-family childcare, as well as generally poor health infrastructures (which render the human capital of educated women less relevant) (Hobcraft 1993). Related to childcare practices, existing literature points out that in Dakar, one often encounters three to four generations living under the same roof. This likely happens both for cultural reasons (including polygamy) and for the relatively high price of real estate, which means that young couples cannot afford to live away from the older generations (Antoine 2003). The aspect of childcare being a matter which concerns the wider family, rather than just of the mother, was also raised by several interviewees. On that account, women from several families living under the same roof often share childcare-related chores. Conversely, families who can afford to do so, sometimes hire young maids from rural areas, who then take on tasks related to childrearing (Delaunay and Enel 2009). However, the interviews revealed that, irrespective of whether the family em-

ployed a nanny, children were still being taken care of by several members of the family or household, suggesting that the adage “it takes a village to raise a child” is often still valid, to a certain extent, in the city of Dakar.

In the current study, having an employed primary carer as opposed to one who is a housewife had no notable impact on the odds of either diarrheal or febrile disease. Although not one of the key variables in the study, according to existing studies, the employment status of the primary carer could influence water-related diseases in both directions (Mihrete et al. 2014; Thiam et al. 2017). On the one hand, employed mothers and carers may have less time to spend with their children and thus be associated with increased risk while on the other hand, housewives may have less access to information and less social capital, which, in turn, would increase the risk faced by their children.

The “other” group in the current study – which consisted mainly of students, apprentices and women doing odd jobs – was associated with an increased risk of only diarrheal disease in the child. This would suggest that the relatively less privileged social status of these women has an impact on diarrheal disease in the children. However, I was not able to confirm or infirm this hypothesis, since most literature compares stay-at-home mothers to those who work. This being said, a 2017 study by Desta and colleagues (2017) which looked at knowledge regarding the home management of diarrhea among caregivers of children under-five from Northwest Ethiopia, also found that women doing odd jobs were less likely to be knowledgeable and have medically appropriate practices.

Regarding household wealth, results of the present research offer little surprise as to the potential impact it has on childhood water-related infections. Generally regarded as a protective factor, increased wealth in the family leads to better overall child health, mainly by increasing quantity and quality of goods and services available to the child (Mosley and Chen 1984). I followed the approach of using household durable goods to estimate wealth, and did this by means of a latent variable, based on ten household durables and estimated via latent class analysis. The resulting latent variable separated the sample of households in three categories: low, average and high. Unsurprisingly, being in the “high”

category was consistently linked to better outcomes, be it in terms of diarrheal episodes, febrile episodes or both. However, the fact that wealth had a protective effect on the occurrence of diarrheal outcomes exclusively and on febrile outcomes exclusively, an effect separate from the one it had on both outcomes together is noteworthy. This indicates that wealth enables households to either live in conditions or afford measures which impact, separately, the risk of diarrhea, but not necessarily of fever, and viceversa.

13.1.3 Behavioral Factors

Hygiene and vector protection are often considered to be among the first line measures against infectious diseases. These preventive behaviors indicate higher levels of health literacy, or parents' motivation and ability to access, understand and implement health-related information in such a way so as to preserve their child's health (Nutbeam 2000). Health literacy is often in close relationship with parents' cognitive and social skills and is translated into biomedically-compatible conduct.

In the current study, health literacy was measured by means of a latent variable at the household level. To create it, I used four indicators regarding comprehension and knowledge, attitudes and behavior regarding health and medicine. The resulting latent variable had a marked impact on water-related diseases. Thus, while its most notable effect was on diarrheal disease, febrile episodes were also associated with lower health literacy in the household. Moreover, health literacy also had a synergistic impact on the occurrence of both symptoms in the same child. However, comparing these results with existing literature can only be fragmentary, since health literacy is a relative new composite term, which comprises both attitudes and behavior. Consequently, to date there are very few studies which deal with its impact on water-related diseases. While very narrow and specific acts, such as handwashing, have been extensively studied in relation to infectious diseases, they generally fail to take into account the broader context related to these acts, which is general health literacy. As Castro-Sanchez and colleagues explain in their meta analysis on health literacy, "the absence of studies related to [...] key health problems such as malaria, [...] associated with large clinical, social, and economic burdens, was

remarkable” (Castro-Sánchez et al. 2016, p. 107).

Another aspect potentially in relation with behaviors, mentioned by several studies, was that of human capital and influences from peers, especially neighbors (Minh et al. 2017). Having dense a social network in the neighbourhood is generally associated with increased subjective well-being and health (Helliwell and Putnam 2004). Part of this relationship could be explained by the fact that a high level of social capital in the neighborhood may influence individuals towards adopting more health-conscious behaviors (Mohnen et al. 2012). For example, Bender and colleagues (2015) found that having frequent interactions with neighbors has an influence, though weak, on one’s health-related behaviors; thus, higher neighborhood social capital would be linked with slightly increased preventive health measures. Along a similar line of thought, Onarheim and colleagues (2017) found that family and neighbors were advice-providers on health-care-seeking behaviors in parents of newborns from Ethiopia.

Consequently, this hypothesis was considered in the current study and the interviews conducted in 2015 had a section dedicated to the relationships of the interviewee with their neighbors and the possible impact they may have on health-related behavior and child rearing. The interviews showed relatively sparse social contact among neighbors in Dakar and, while not constituting a representative image of the city, they suggest that urban Senegal does not maintain the same social ties with neighbors as it happens in rural areas. However, contrary to the aforementioned expectations, people interviewed in the four neighborhoods of Dakar mentioned few relationships between neighbors and they were generally on a superficial level, of “‘hello’s, ‘good evening’s [...] otherwise, each of us is in their house” (Idrissa, 59, man, Dalifort). In this context, it seems relatively unlikely that a meaningful amount of health literacy diffusion occurs at the neighborhood level.

Another aspect which can potentially also influence individual behavior regarding health are characteristics of the environment. For example, the current study has shown that perceptions regarding the potableness of drinking water influence treatments applied to it. Color and deposits were particularly prone to leading individuals to either add bleach or leaving it in containers overnight, in

order for deposits to set on the bottom of the container. Contrarily, when the water appeared clear, the people interviewed generally did not apply any treatment to it, prior to drinking. Similar findings were reported by Dos Santos (2011) in Ouagadougou, Burkina Faso. There, traditional beliefs coexisted with an emerging attainment of the biomedical model with regard to health, leading to diverse representations regarding water in the domestic sphere.

Another example of the relationship between environment and behavior raised by the current study was that of anti-mosquito measures. Chapter 11 extensively analyzed the relationship between mosquito nuisance and mosquito-borne febrile illnesses. Since Dakar is a large city and since its environment is highly heterogeneous, the density of mosquitoes in the area differs from one neighborhood to another, as function of the surroundings. The quantitative and qualitative analyses of this study show that mosquito presence in the area impacts both on individual/household behaviors and on the risk of being bitten, leading to reverse causation in the assessment of the role that bed nets have on individual mosquito-borne fevers.

Although similar findings were reported in existing literature, to my knowledge, there has not yet been research to specifically deal with this aspect. Several studies in Sub-Saharan Africa suggest that the use of bed nets is associated with mosquito density or nuisance in the area (Alaï et al. 2003; Iwashita et al. 2010; Thomson et al. 1994; J. Thwing et al. 2008). In some cases, individuals and households only use bed nets during the rainy season, when mosquito density is higher, while during the rest of the year they forgo the use of bed nets, generally due to reported excessive heat (Binka and Adongo 1997; Winch et al. 1997). Moreover, “it seems that the main purpose of bed net usage is to protect against mosquito bites rather than to prevent malaria” (Toé et al. 2009, p. 2), which means that individuals are likely to use bed nets when there is high mosquito nuisance, rather than to prevent mosquito-borne infections. Hence, despite the continual risk of infection in Sub-Saharan Africa, in situations when mosquitoes constitute less of a nuisance, protection offered by bed nets is undermined (Toé et al. 2009). On a sidenote, the relationship between mosquito nuisance and other anti-mosquito measures has also been reported. For example, in

the city of Dar es Salaam, Tanzania, the sale of mosquito coils was in close relation with the density of female *Culex quinquefasciatus* mosquitoes (Chavasse et al. 1996).

One article presents this relationship between the use of a bed net and increased malarial prevalence in Ethiopia, suggesting that the use of bed nets is a function of (perceived) risk of mosquito bites (Graves et al. 2009). However, the association is not further investigated by the authors. Similarly, in a bivariate analysis on data from a survey done at several health centers in rural Niger, there was a statistically significant association between the household bed net use and testing positive for malaria infection upon admission. Thus, using a bed net was positively and significantly associated with malaria infection, but the authors did not further analyze this aspect, as the focus of the study were the outcomes of ACT treatment, rather than the determinants of malarial episodes (Oldenburg et al. 2018).

The quantitative results of this study also found a significant association between using bed nets in general in the household and children experiencing both febrile and diarrheal episodes. Subsequently, the qualitative information suggested where the origin of this association may lie: areas prone to high mosquito densities tend to also suffer from high populations of flies, which are potential vectors of several diarrheal pathogens (S. W. Lindsay, T. C. Lindsay, et al. 2012). Regarding this relationship between bed nets and the co-occurrence of both symptoms, Kazembe and Namangale (2007), using data from the 2000 Malawi DHS, found a slightly increased relative odds ratio for the co-occurrence of febrile and diarrheal episodes when the household owned bed nets and slightly decreased relative odds ratio for the co-occurrence of febrile and diarrheal episodes when the household declared using bed nets. However, since the associations did not reach statistical significance, the authors did not develop on this aspect.

13.1.4 Environmental Factors

Dwelling and area-related environmental factors, as well as their impact on water-related diseases, are one of the main focal points of the current study. Three latent variables were created, by means

of latent class analysis. The first one, at the household level, measured the dwelling amenities and quality of construction. The second and third ones, at the neighborhood level, measured the coverage and perceived quality of access to water, wastewater and solid waste management. At the household level, the latent variable included indicators regarding access to water, wastewater and solid waste disposal, as well as roofing and window materials. While its impact on diarrheal episodes was quite a marked one, it did not appear to have a significant effect on febrile episodes. On the other hand, when analyzed at the neighborhood level, the situation was reversed: access to water, wastewater and solid waste management had an important and significant impact on the occurrence of febrile episodes in children. These are two complementary findings, which could be related to the fact that having improved water source and sanitation in the dwelling may help minimize the risk of ingesting contaminated water, whereas the presence of mosquitoes and vectors of water-related diseases in general is more influenced by the presence of stagnant waters and garbage dumping sites, both of which depend on the sanitation infrastructure at the neighborhood level.

However, it was only the subjective, perceived quality of sanitation which had an impact on febrile episodes, while the objective, measurable indicator of sanitation – coverage – did not have any notable effect on any of the symptoms investigated. This finding is pursuant to one of the formulated in this study, whereby measurable indicators, such as coverage and types of facilities, may not accurately represent the quality and functioning of the aforementioned facilities. To date, scientific literature has yet to address the issue of sanitation in a more comprehensive manner, by including more indicators of quality and of the beneficiaries' level of satisfaction with the provision of sanitation infrastructures. This is despite the fact that issues regarding the commonly used statistical indicators – which most often dichotomize water and sanitation facilities at the household level into “improved” and “unimproved” – have already been raised, most notably in the UN-HABITAT report of 2007 (United Nations Human Settlements Programme 2006),

In the current study, the aspect was further investigated in the 2015 interviews. Here, several of the interviewees mentioned flaws

in the sanitation system, which cannot be accounted for by merely using statistical modeling. Among these aspects, one of the most remarkable was probably related to septic tanks. Thus, due to the cost involved in calling a wastewater emptying truck, during periods of heavy rainfall, some inhabitants from neighborhoods located uphill would open their septic tanks so that the rainwater would drain away the contents. This would, in turn, impact on those living downhill, whose streets and houses would get flooded with rainwater mixed with wastewater. Similarly, some families resorted to discharging wastewater in the street, which would then impact primarily not the family in question, but those in the immediated proximity of the dumping ground (Heller 1999).

Another aspect worth noting in relation to the quality of provision was that, while most of the families interviewed were connected to the running water network, many of them experienced frequent and irregular, unannounced water cuts. This meant that although they officially had running water, the affected households had either to resort to alternative means of procuring water or to store it inside the dwelling for prolonged periods of time, which constitutes a risk for indoor mosquito breeding (Tsuzuki et al. 2009).

Consequently, as with health literacy, putting the current study's results in the context of existing literature cannot be done in a comprehensive way. Aside from the shortage of studies integrating indicators of quality of provision, existing literature on the topic generally does not distinguish the household/dwelling environment from the area-level one. However, the role of various environmental factors in water-related diseases has been amply documented, but most of the existing literature looks at the difference between improved and unimproved facilities either in the dwelling or at the community level, but rarely includes both.

Most of the existing literature looks at the difference between improved and unimproved facilities, since the lack of improved sanitation mean excreta can come in contact and contaminate underground water sources (Buttenheim, 2008; Graham and Polizzotto, 2013, cited by Vásquez and Alicea-Planas 2018). Decomposing risk factors for diarrhea DALYs in the Global Burden of Disease Study of 2015, Troeger and colleagues (2017) found that among the ten total risk factors for diarrhea, the two leading ones were unsafe

water and sanitation and malnutrition.

In a meta-analysis done for the WHO, the median reduction in diarrheal disease associated with improved access to water and sanitation was 20% and 22% respectively (Esrey et al. 1991). Another meta-analysis reported similar findings from several studies, but they were not statistically significant (Hamer et al. 1998). Alagidede and Alagidede (2016), using water and sanitation indicators from the World Development Indicators, explain that the interaction between poor sanitation and poor access to water leads to additional risk of water-related diseases, both water-borne and vector-borne.

Also using a DHS survey, the 2008-2009 one for Kenya, Mbugua and colleagues (2014) found increased odds of diarrheal diseases in children from households using well-water, compared to household using piped water. The authors did not find a statistically significant association with the type of toilet used by the household. On the other hand, still with DHS data, Mihrete and colleagues (Mihrete et al. 2014) on the determinants of diarrheal disease in children under five from North Western Ethiopia, found that both unimproved water sources and toilets lead to increased odds of diarrheal infection. Similar results concern a study performed in four villages in Southern Malawi in 2006, dealing with risk factors for diarrhea (Masangwi et al. 2009).

Going beyond the improved-unimproved dichotomy, some aspects related to the reliability of provision have – albeit to a much lesser extent – been addressed. In this perspective, a 2016-2017 study focusing on dengue in Saudi Arabia and using blood samples to assess dengue infection, had similar findings, whereby both having an irregular water supply and lacking connection to the sewage network were significantly and positively associated with the odds of having high seroprevalences of dengue antibodies in the blood (Al Raddadi et al. 2019). The study also found that not being connected to the sewerage network constituted a risk factor for dengue infection, although due to the employment of a fixed-effects model, the relative impact of environmental factors could not be assessed.

The presence and type of canals in the neighborhood was also in-

vestigated in the present research. A seasonal canal was associated with increased odds of febrile episodes in children from the neighborhood (despite the very low sample, of only 2 neighborhoods with seasonal canals) and, when treating each symptom in a mutually exclusive way, it had a similar impact on the odds of experiencing both a febrile and a diarrheal episode. The 2015 interviews revealed that seasonal canals often constitute not only a body of water, but also a salubrity issues, due to solid waste clogging. This is due to the fact that in Dakar, the main role of seasonal canals (dry during most of the year) is to drain rainwater. During the most of the year, as they are dry, they often serve as waste disposal areas, which blocks the evacuation flow, thus causing them to overflow during the rainy season.

13.1.5 Levels of Analysis

One of the aims of this research was to investigate contextual effects on individual health. This is because individuals from the same group, such as the household or small neighborhood are, to a certain extent, interdependent. Consequently, what influences one group member may also influence other group members, by direct interactions or by an indirect common environment (Feaster et al. 2011). In short, contextual processes at the community or geographical area-level may play a role on health and health inequality (Macintyre, Maciver and Sooman, 1993, cited by Dunn and Cummins 2007).

The statistical modeling used in the study involves three levels of analysis: the individual (the child and their mother/carer), the household and dwelling and the neighborhood. This allowed to decompose the variability in the explained indicators – diarrheal and febrile episodes in children – so as to identify the part of risk imputable to each level. The results showed, as would be expected, that the proportion of variability successively decreases the higher the level of analysis, with the largest part of the risk lying at the individual level and the lowest one at the neighborhood level. However, since these decomposition indicators function for estimating impact in a relative way, this means that the high relative impact of one level automatically translates to a low relative impact of the other levels. However, relatively limited relative effects may render

significant changes, in absolute terms, when they apply to large numbers of observations. Hence, in terms of absolute impact, a difference of one or two percentage points in incidence between different areas can translate into many children finding themselves at increased risk, due to their environment. As a corollary, interventions undertaken at the area level, since they impact large numbers of people, may lead to significant reductions in the absolute numbers of those affected by water-related diseases.

Most existing literature also points to the fact that the impact of the area (such as the neighborhood) is generally small when compared with individual-level effects, mainly with regard to socio-economic status (Diez Roux 2001, p.1787). As a result, research generally focuses on the dwelling when looking at environmental factors. In part, this may also be due to availability of the data, since many studies on diarrheal and febrile episodes in children use DHS data; and DHS data does not provide location information regarding survey participants, for privacy reasons. However, in research that has looked at area-level determinants, proximity to water (stagnant or flowing) and sanitation are the most often cited (Fewtrell and Colford 2004; Guthmann et al. 2001; Keiser et al. 2005; Staedke et al. 2003)

Aside from including these indicators in the statistical analysis and providing an estimate of the relative role of individual *versus* household *versus* neighborhood for water-related diseases, the present study also addresses the value of analyzing the data in a hierarchical manner. The indicators used to assess the relative effect of the higher levels suggest that, although relatively small, the degree of clustering of water-related diseases by area needs to be taken into consideration. Thus, a single-level model (and even a two-level model) would have lead to underestimated standard errors and hence, to potentially flawed conclusions. The design effects of the models show that using a multilevel approach is, leaving theoretical considerations aside, relevant in the study of water-borne and mosquito-borne infections.

The quantitative results hinted at an association between spheres (behavior and environment) and levels of analysis (neighborhood and household sanitation), but the qualitative approach allowed to further investigate these aspects. The interviews showed that

not only are spheres of lives of individuals and families are highly intertwined, but also that borders commonly used to delimit an area may not accurately render realities on the ground. Thus, living conditions and the environment in one neighborhood can affect the inhabitants of other nearby neighborhoods. These aspects are difficult, if not impossible, to address by quantitative approach only.

13.2 Strengths and Limitations of the Current Study

There are, of course, some aspects that need to be taken into consideration when analyzing the results of the present study. In the following pages, I will discuss these limitations and the strategies adopted to limit their potential bias on the results obtained. Subsequently, I will also present what are, in my opinion, the main strong-points of this research and its added value in the context of water-related disease research.

In terms of the two symptoms tested, there is first and foremost the declarative nature of the explained variables. Febrile and diarrheal episodes have not been observed by researchers and they also have not been objectively measured, but rather assessed by questionnaire. This means that the respondent of the household questionnaire, who was most often the head of household or their spouse, was interrogated about whether or not the child in question had experienced such a symptom in the recall period. While of course the respondent could consult the mother or primary carer of the child to accurately answer these questions, this does not exclude bias brought about by the mother's/carers' declaration. There are no reasons to suspect deliberately faulty answers from either of the participants involved in answering this question, but either a lack of noticing such an episode in the child or issues remembering it may lead to some inaccurate answers.

The first issue, that of needing to have taken notice of a fever or diarrhea in the child, is typical of all self-assessed data and refers to the fact that, as opposed to medical check-ups, it depends on subject's (or his/her tutor's) perception, knowledge and interest in

health. These may, to a certain extent, vary according to socio-economic status and cultural attitudes regarding illness (Seigel et al. 1996; Woldemicael 2001). For example, mothers and carers who place more value on health and prevention could be more inclined to notice abnormalities in the child's body temperature or stools. Including socio-economic variables regarding the mother, such as being able to read/write and occupation can partly mitigate this potential bias. However, generally formal education does not entirely explain individual propensity to care for one's health and for the health of their children. Hence, including a latent variable which measures specifically health literacy can better control for the primary carers' potentially differing knowledge, motivation and behaviors related to health

The second issue, that of remembering whether or not the child experienced a water-related diarrheal or febrile episode, also called recall bias, may introduce some erroneous answers in the data, especially for longer recall times, such as is the case in the ACTU-PALU survey (Fewtrell and Colford 2004; Woldemicael 2001). However, the goal of the current research is to test the impact of behavioral and environmental factors on water-related diseases. So, while inaccurate answers due to recall issues are possible, there is little reason to believe that a failure to remember such an event is in relation with either environmental living conditions or with behavioral practices, but rather with aspects such as age or individual forgetfulness. Hence, recall bias is not likely to affect different categories of population to different extents. Somewhat related to this, is the fact that, across the two types of symptoms, the recall times were not the same: for diarrheal episodes, the respondent was asked if the child had experienced it in the previous fifteen days, whereas for febrile episodes, the period concerned was the previous thirty days, and the child had to have recovered since at least three days. Again, while that needs to be kept in mind, there aren't reasons to believe that this introduces systematic bias in the relationship between the determinants considered and each of the variables of interest, since no meteorologic indicators were used in this study.

In terms of the determinants considered, in the quantitative data available it was not the child's mother who was documented, but rather children were listed under their primary female carers. This

means that the person listed as the child's carer may not have been their biological or adoptive mother, but a grandmother, aunt, older sister or other female family member. For this reason, as well as to gain additional insights into the organization of family life in Dakar, the interview guide contains a section about childcare practices and secondary childminders.

Regarding neighborhood sanitation, the latent variable which estimates its subjective quality is, indeed, subjective. Since the questions used to estimate it refer to the perceptions of a group of individuals⁴. This means that, on the one hand, their opinions may not be representative of the whole population of the neighborhood, because what constitutes perfectly acceptable conditions by one person, may be regarded as fundamentally deficient by another. On the other hand, with only one value per neighborhood and fifty neighborhoods in total, the statistical power of this variable is somewhat limited. Still, using this latent variable to assess the sanitation perceived quality of the neighborhood does give a glimpse that currently used quantitative measurements and indicators (most often related to whether or not the household has improved sanitation and water sources or to the coverage of sanitation infrastructures in the area) may not, in itself, accurately reflect the living conditions of households in urban contexts from the developing world.

Moreover, with regard to sanitation, the perceived quality seems to better predict the occurrence of a water-related infection than indicators related to coverage. The fact that it was also statistically significantly associated with the perception – at the household level – that malaria constitutes a problem in the neighborhood, seems to confirm this.

In terms of anti-mosquito measures, the question measuring them is, as in most research in social sciences, a self-declarative one, asking participants “How do you protect yourselves from mosquitoes in this household?”. Both the self-declarative nature of the variable and the abstraction of the question make it prone to personal interpretation, since the quality and potential user-error associated with the methods in question have not been measured. On the

⁴The respondents of the community survey

other hand, asking people what method they used in the previous night would also have incurred the risk of inaccurate answers, as some people use, depending on the situation, one method or another (or no method at all). However, to partially mitigate for potential bias, I added additional statistical analysis involving this variable, as well as further investigated the link between mosquito nuisance and mosquito protection by means of interview.

Regarding the qualitative data collected in 2015, the interviews were limited to only four neighborhoods, due to both cost and logistic considerations. This means they are not generalizable to the whole area of Dakar. However, they do provide an additional, more in-depth, insight into some of Dakar's living conditions, childcare arrangements and health-related practices.

This being said, the study also benefits from certain advantages in the context of existing research on the topic of behavioral and environmental determinants for water-related diseases in children.

Possibly the most important asset of this study in terms of quantitative analysis is the ACTU-PALU data, which has been used as the main quantitative source of information, and which is a rich source of hierarchical data on urban living conditions in Dakar. Many studies dealing with infectious diseases focus on either the impact of private individual or family actions related to hygiene and protection or on the impact of measures undertaken at the area level (most often to improve access to water or sanitation). It is less often that research integrates both the behavioral and the environmental spheres (most often due to limitations related to existing data), which makes it difficult to assess the relative role of each of these spheres in water-related diseases.

As opposed to data from surveys such as the DHS or the MICS II, which carry information on the individual and the household, the ACTU-PALU database also includes variables pertaining to the immediate area of the dwelling. Since the indicators are split as by "layers" (first the child in question, then their carer, then the family they live in and finally, the neighborhood where the dwelling is located), this allows for decomposing the source of the variability in febrile and diarrheal episodes by level. Consequently, the part imputable to individual characteristics can be distinguished from

that pertaining to the household and from the one due to the milieu. In order to do that, as well as to fully take advantage of this hierarchical structure of the data, a multilevel statistical analysis is needed, which is what the present research employs.

One of the characteristics of multilevel methods is that they generally tend to employ a large number of explanatory variables, since they require covariates for each of the levels considered. Consequently, in order to produce a thorough analysis of the phenomenon in question, models run the risk of becoming difficult to interpret or even to estimate, on a sample of a given size. With this in mind, I employed LCA, a technique which is used relatively often in developmental studies and socio-economic research, but much less in population and epidemiologic research. LCA allows to include a multitude of factors in the analysis, but in a synthesized manner, thus limiting the risk of an overfitted model. On that account, the full model contains 10 covariates for diarrheal episodes and 13 covariates for febrile episodes. However, without the use of LCA, the models would have consisted of 33 and 36 covariates, respectively. This poses a serious risk of overfitting the noise in the data, thus yielding an unstable model with large standard errors for each parameter and very low power to detect most of the effects (Zhang 2014).

Latent variables, when used in social and public health studies, are most often employed for reducing several dependent variables to one, more general, “health status” variable (Khatab and Kandala 2011; Landale et al. 2013). This has the advantage of making statistical modeling (such as regressions) more convenient. However, despite its obvious statistical advantages, LCA has been so far significantly less used for reducing the number of dimensions in the independent variables.

In that sense, while other studies have looked at area-level determinants, the present research allows, at the same time, to quantify and, thanks to its mixed methods approach, draws attention to the intertwined nature of environmental factors, between the dwelling and the neighborhood. Drawing from that, both the quantitative and the qualitative analyses comprise a rather large sphere of potential risk or protective factors, which provide a relatively complex picture of the determinants of water-related diseases in urban

children, as well as of the interdependencies between these determinants.

Similarly, there have been several articles published on the topic of diarrheal-febrile co-morbidity, but most of them use DHS data. This means that, due to the nature of DHS data, none of the aspects pertaining to the area could be studied, despite the interrelation – as the current study has shown – between environmental determinants at the household and at the area levels. Moreover, existing literature using data other than the DHS program and investigating the role of sanitary infrastructures (access to water, sanitation and solid waste disposal), usually does not address the difference between these facilities at the household/dwelling level from the area level. This poses significant risks of confounding factors resulting from discrepancies between households in the same area, as Heller (1999) pointed out.

The concept of health literacy is among the key factors necessary to improve public health and for this reason, the WHO called for action at different levels to remedy low levels of health literacy in the general population (Van den Broucke 2014). However, the concept is a relatively new one, which means that literature addressing this issue remains quite limited, despite some advancements in recent years. Moreover, the vast majority of existing research involving health literacy deals with Western, developed contexts and is almost exclusively focused on the impact it has on degenerative and lifestyle-related diseases. As Castro-Sanchez and colleagues (2016) point out, in terms of infectious diseases in general, the body of evidence regarding health literacy is very limited and fragmentary. Despite the fact that infectious diseases constitute, by excellence, a fertile ground for investigation regarding interactions with health literacy⁵, there is a marked gap in knowledge concerning the relationship between the most essential aspects of health literacy, such as hygiene and protective measures for example, and infectious diseases (Castro-Sánchez et al. 2016). By including both a latent variable which estimates health literacy at the household level and by addressing behavior and motivations for protective measures in the interviews, the current research helps to fill a small part of this

⁵This is mainly due to the multitude of decisions and measures involved in prevention and self-care (Castro-Sánchez et al. 2016)

gap. The study does not merely look at the knowledge or education about a specific disease, but rather estimates a more global propensity to adopt biomedically appropriate behavior and the knowledge of reasons behind it.

Another less investigated area with regard to water-related diseases in children, most likely due to the scarcity of data, is that of older children, more specifically those aged five and above, who tend to have different circadian rhythms and daily activities than their younger counterparts, thus experiencing different levels and sources of exposure to pathogens. While assessing risk factors in children under five in developing contexts has been possible in many cases thanks to data from projects such as the DHS and the MICS II, these surveys cap the age of children for whom infectious diseases are documented at fifty-nine months, so just under five. This resulted in lacunas with regard to older children's risk factors, which may be slightly different than younger children's, due to different exposure, lack of breastfeeding and a more mature immune system. Moreover, research on babies and toddlers shows a sharp increase in risk towards one year old, followed by a slow decline afterwards, but little is known past the age of five, since data usually does not cover subsequent age groups. The present research uses data on children aged two to ten and showed that age continues to provide additional protection against water-related pathogens past the age of five. It also revealed that, while most determinants have the same impact on younger and older children, aspects such as mosquito protection may have distinct impacts on different age groups, probably due to diverse circadian rhythms. Stratified regressions by age category (children under five and children aged five and above) found differences in the effects associated with anti-mosquito measures, most notably regarding the use of bed nets. Thus, it seems likely that in areas with high mosquito densities, older children could face additional risk of mosquito bites, probably due to them staying up later and spending more time outdoors. This has potential implications both in terms of research and in terms of public health measures (See Chapter 14).

So far relatively less studied, the relationship between mosquito presence or mosquito nuisance and the use of mosquito nets was analyzed both in a quantitative and in a qualitative manner. To

this end, the current study adds the component of individuals' perception regarding mosquito presence and mosquito nuisance in the area, whereas studies done on this topic generally only assess the property of nets to limit mosquito bites while they are being used or only investigate the reasons for non-use in the general population. However, as some of the interviewees pointed out, mosquitoes become active at dusk (and in the case of some mosquito species, they are especially active during the day), which means that the same persons who tend to use mosquito nets during sleep (because otherwise mosquito bites disturb their sleep) are more likely to be bitten, before going to sleep. Moreover, individuals' perception of having high mosquito densities in the neighborhood proved to have a significant association with their propensity to take measures against mosquito bites. In this sense, the investigation carried out in the current research is, to my knowledge, among the most in depth among existing studies on the topic. Consequently, it also adds information on reasons and motivations for non-use and can provide a starting point for campaigns aiming to increase bed net use.

There are several other advantages associated to using a mixed methods approach. One of the most important ones, illustrated by the present research, is that adding qualitative techniques can, in many instances, mitigate for specific problems inherent to quantitative data. In this case, triangulating the two approaches increases the credibility and validity of the results (Randall and Koppenhaver 2004). One example of this is revealing the fact that while some households/neighborhoods officially benefit from improved sanitation, this was hardly the case, due to issues in quality and reliability or to the fact that, when broken, infrastructures were often left unrepaired. Hence, using statistical indicators alone would not convey an accurate picture of the real current situation of these families and areas.

Along the same line, using mixed methods allowed to point out that separations between neighborhood are often more blurred than the official administrative borders. Consequently, environmental conditions in one neighborhood can be influenced by landforms and sanitation in adjacent neighborhoods or areas located in its vicinity. Using only statistical methods would have made it very difficult, if not impossible, to reveal the fact that households uphill use heavy

rain showers to drain their septic tanks, or that in some neighborhoods, although a sewerage network exists, it is malfunctioning or unusable.

Another added value of the interviews, as Randall and Koppenhaver (2004) point out, is that they allowed, on the one hand, for testing different hypotheses yielded by the quantitative analysis, as well as to explain surprising, counter-intuitive aspects, as well as relationships which do not reach conventional levels of statistical significance. One example of this in the current study is the aspect of secondary carers for children or association between anti-mosquito measures and mosquito nuisance. On the other hand, qualitative analyses allow to investigate the particular ways in which people think, as well as to examine this wide range of opinions, knowledge and attitudes on a given topic.

Another main goal of this research was to assess the relationship between characteristics of the area and individual health. As Diez-Roux (2001) states, this requires different research designs, depending on the type of study. Quantitative studies need, on the one hand, to analyze data on both individuals and the areas in which they live. On the other hand, they need to be performed on data with sufficient neighborhoods and sufficient individuals per neighborhood. Conversely, qualitative research facilitates “elucidating the processes involved as well as the dynamic interactions between area and individual characteristics, which may be difficult or impossible to examine via purely quantitative approaches” (2001, p. 1787)

Along this line of thought, the current study combines both a quantitative approach and a qualitative one. On the one hand, the quantitative part includes a fair number of neighborhoods and a large number of households and children in each neighborhood. This allows, at the same time, to create a broad picture of the causal relationships involved and to measure within and between group variability in water-related diseases. On the other hand, the qualitative part focuses on four contrasting⁶ neighborhoods, so as to better grasp specificities and better understand the mechanisms at play in each of these contexts.

⁶From the perspective of the two symptoms investigated

Diez Roux (2001, p.1787) also adds that “combinations of quantitative and qualitative approaches may be especially useful” and that joining small-scale in-depth analyses with large-scale modelling of statistical data “is a promising area”. In that sense, I reckon that, with a mixed methods approach, this study conveys both a broad picture of the determinants of water-related illnesses in urban children and a more in-depth investigation of particular environmental and social conditions in specific neighborhoods. The study thus examines the within- and between- neighborhood variability, but it also delves into more precise areas, to investigate the mechanisms at play.

In conclusion, the research uses a multilevel statistical analysis with latent variables, combined with photographic material and interviews. This approach, in its entirety, allows to account for a multitude of factors from different spheres and at different levels, which impact, to different extents and by different paths, the risk of water-related infections. Additionally, combining quantitative and qualitative data and analyses in an explanatory design, allows to better explain the significance of statistical results, the specificities of outliers and certain apparently surprising results (Creswell 2011).

The study focuses specifically on children living in an urban context, namely the city of Dakar. Such a heterogeneous and rapidly changing environment raises additional challenges in terms of infectious diseases. Spatial promiscuity in terms of living arrangements, crowding, unsalubrious living conditions are just some of the factors that make urban children more at risk than rural children in developing contexts (Mbugua et al. 2014).

Chapter 14

Conclusions

Almost two decades after the United Nations General Assembly first laid out the MDGs – with a general timeframe of fifteen years – most of the objectives related to infectious diseases are yet to be attained (United Nations General Assembly 2000). In Sub-Saharan Africa, while for under-fives, death rates from diarrheal diseases have steadily declined, the progress has been much slower in older children (Institute for Health Metrics and Evaluation (IHME) 2017). Even more worryingly, despite the United Nations’ attempts to halt and begin to reverse the effects of malaria, death rates from malaria increased in older children from Sub-Saharan Africa, despite having halved in under-fives (Institute for Health Metrics and Evaluation (IHME) 2017). This shows that water-related diseases, far from being an affliction of the past, still constitute one of the most concerning public health issues for most of Sub-Saharan Africa.

The unfortunate course of events leading to this failure of achieving the MDGs has been fuelled by, among others, antimalarial drug resistance and the lack of a significant improvement in the lives of the ever-increasing number of slumdweller from across the developing world.

In this context, the study has focused on the city of Dakar, aiming to identify the factors favoring (or deterring) infection with water-related pathogens in children, as well as links between these determinants. The location of the study, the capital of Senegal,

is a large and very diverse Sub-Saharan African city, with a rapid rate of urban growth. The children considered in the quantitative analysis were aged between 2 and 10, so as to limit the potential bias of breastfeeding and to provide information regarding infectious diseases in older children.

The main hypothesis of the study was that a relatively large range of factors – belonging to different spheres and levels of analysis – concur, each to a small degree, to determine the water-related disease outcomes, rather than a small set of strong determinants. In other words, the expectation is that water-related diseases follow a pattern of causality similar to that of the Mandala of health (Hancock 1985), whereby biological, socio-economic, behavioral and environmental factors all play a part in determining the outcome in terms of morbidity.

The evidence gathered by the research seems to support the framework put forward in the Mandala of health, in the sense that factors related to individual conduct, to socio-economic conditions, to biological factors and to the milieu conjointly interacting to determine the health outcomes, both in terms of diarrheal and in terms of febrile water-related episodes.

A second hypothesis concerned the relative “share” of each level – the individual, the household and the neighborhood – expecting that, while each of the three levels will explain some of the variability in diarrheal and febrile episodes respectively, the largest part will refer to the child. For both outcomes, the statistical analysis showed that respectively 76% and 87% of the variability lay at the individual level. Moreover, at the neighborhood level, while the variability was relatively low, the models employed by the present research explained a third and half of the residual variability, respectively, in terms of diarrheal and febrile outcomes.

Thirdly, the study started from the premise that, albeit the transmission mechanisms differ between the two types of water-related diseases (diarrheal and febrile), the majority of determinants would be similar.

The statistical analysis of the ACTU-PALU dataset revealed a set of common determinants for both diarrheas and fevers, from each of the four spheres investigated: demographic, socio-economic, be-

havioral and environmental. Thus, the child's age had a positive role in protecting against both types of infection, just as did the family's wealth. Most notably with regard to behavioral factors, health literacy had a relatively strong and consistent effect on each type of infection taken separately, but also a synergistic effect on the co-occurrence of both diseases. It is also to be noted that health literacy had an own effect, different and independent from those of the main carer's education and of the household wealth.

The statistical analysis of co-morbidity interviews also pointed out that bed nets were strongly associated with fevers, but also associated with the co-occurrence of both fevers and diarrheas, despite not having a significant association with the occurrence of diarrheal episodes exclusively. Regarding this aspect, the 2015 interviews pointed out that the presence of mosquitoes is often linked with that of flies, thus offering a plausible explanation for this finding.

Regarding the environmental sphere, most notably sanitation, it impacted on each of the symptoms, but in different ways: household amenities were associated with the outcome in terms of diarrheal infections, while the perceived quality of the infrastructures at the neighborhood level were associated with febrile infections.

As mentioned in Chapter 5, a fourth hypothesis of the study concerned the possible inter-relations between factors, spheres and levels, with three sub-hypotheses concerning this topic.

I was expecting, firstly, for the sanitation facilities and their usage at the household level to generally be a function of the provision at the neighborhood level. This aspect was addressed in the 2015 interviews, which, by and large, supported this hypothesis. Thus, those individuals and families living in neighborhoods without sewerage (Dalifort and Fith Mith) most often mentioned alternative solutions, such as hole-digging or impromptu discharging of wastewater, whereas those living in neighborhoods where a sewer network was present, mention conventional wastewater discharging methods, as the sewers "never fill up" (Sawdiatou, 25, Unité 8). In terms of access to water, Similarly, issues with the reliability of the garbage truck passage in the neighborhood prompted household strategies such as freezing household waste, to avoid it decomposing, or bury-

ing in a hole common to several households.

Secondly, I was expecting that discussions with neighbors influence mothers' health-related knowledge and conduct. However, this hypothesis was clearly refuted by the qualitative section of the research, as the vast majority of the interviewees pointed out that relationships between neighbors in Dakar do not retain the traditional, village-like ties and are, for the most part, polite but without interpersonal depth.

Thirdly, I was expecting that the main carer's or the family's socioeconomic status interact with the household amenities, on the odds of water-related illnesses. Along the line of thought of the education gradient, I was expecting that more educated or wealthier households would be able to develop more "coping mechanisms" to offset the negative effect of lacking infrastructures in the dwelling. However, as the statistical analysis showed, the data does not support such an interaction regarding Dakar's children.

Also under this topic, two aspects arose subsequently. The first one was the relationship between behavior and environment, namely between the usage of anti-mosquito measures and the perceived presence of mosquitoes. Both the statistical analysis and, especially, the interviews, provided an insight into the mechanisms and reasons of using mosquito bite prevention methods. The second one was related to the inter-relations between neighbors and neighborhoods, in terms of the impact of alternative strategies regarding sanitation and solid waste. Here too, the interviews underlined that actions undertaken by families in an area can impact neighboring families, but also families living in other areas.

Finally, the fifth main hypothesis regarded the validity of the statistical indicators measuring sanitation, in a fast developing context such as the city of Dakar. I hypothesized that the currently used measures of coverage would hide disparities in terms of the quality of provision. While the statistical analysis hinted in this direction (the latent variable measuring the coverage of sanitary infrastructures did not impact on the odds of mosquito-borne fevers, the one measuring the perceived quality did so), the interviews and community survey revealed several aspects which pinpoint specific issues regarding the use of coverage as proxy for access of the popula-

tion. On the one hand the topic of wastewater drainage proved to be an extensive one, revealing a multitude of alternative strategies adopted by inhabitants, which sometimes impacted on other households or even other neighborhoods. On the other hand, the upkeep of such infrastructures was also mentioned as an issue: although electricity was available in Soprim 1, since the lightbulbs had long been unchanged, most of the streets were actually unlit.

Therefore, analyses in this research advance knowledge of the relationship between behaviors, the immediate environment and the most common manifestations of water-related infections: diarrheal and specific febrile episodes.

In particular, the findings point out that health-related behaviors in the family are often a function of the immediate environment. For example, treatment applied to drinking water was generally a direct function of its (perceived) potability. Similarly, households from mosquito-prone areas were extremely likely to take measures to ward off mosquitoes, mostly at night, while households from areas with relatively few mosquitoes were more enclined not to use any measures. These observed interdependencies and interrelations between levels (individual and household behavior being a function of the immediate environment) call attention upon the necessity to take into account characteristics of the wider area, when researching infectious diseases (Clarke et al. 2002).

As already mentioned, some issues have been raised in recent years with regard to the “improved” / “unimproved” dichotomy when analyzing access to water and sanitation in the developing world (Shaheed et al. 2014; United Nations Human Settlements Programme 2006). The current study helped reveal some of the reasons why “improved” water sources and wastewater disposal facilities are not always reliable or safe. The qualitative research yielded several elements that would have been hard, if not impossible, to spot via the use of statistical data alone. In doing so, the research pointed out that some of the commonly used statistical indicators of living conditions in the developing world may not convey an accurate picture and that more in-depth, qualitative analyses are often necessary to accurately understand potential risk factors for infectious disease transmission.

While wide-scale standardized programs such as DHS and MICS have provided data to investigate the effects of the environment inside the dwelling (particularly the presence of an improved drinking water source and the type of toilet), there is significantly less data available regarding the area. However, as the current study showed, the two – residence and surroundings – cannot be studied apart from each other. Indeed, improved facilities in the household offer little protection if the corresponding infrastructures are not present in the area or if the neighboring households are not, also, connected to these infrastructures. Going even further, sanitation in one neighborhood may be influenced by conditions in other – generally adjacent, but not solely – neighborhoods. This, again, corroborates the need to investigate living conditions both in a statistical and in a non-numerical manner.

These are the main findings, described in the previous chapters of this thesis. At the end of this doctoral research, in the few pages remaining, I will briefly lay out the outcomes of the study, first regarding possible ramifications of the current study into different areas of action and secondly regarding prospects of subsequent studies.

14.1 Potential Implications of the Findings

Analyses in this study expand the understanding of what constitutes a risk for water-related diseases in children from urban Sub-Saharan Africa. The topic of individual and public measures to undertake to reduce childhood infectious diseases is one of broad and current interest all across the developing world.

In the context of an ongoing debate regarding whether it is private actions or external physical conditions which shape the outcomes when it comes to water-related infections, the present study's findings point to both behavioral and environmental factors, each of which had significant effects on both diarrheas and fevers due to water-related infections.

On the one hand, environmental factors, both in terms of sanitary infrastructures and in terms of landscape had significant impacts on

water-related symptoms, despite the small number of observations at the neighborhood level. Qualitative results showed that statistical indicators may hide deficiencies of the general infrastructures, which makes them less reliable than their counterparts in Western contexts. For example, in Soprim, although a street lighting network existed and thus the neighborhood officially had public street lighting, it had long ceased to be functional.

These findings have obvious implications in terms of both public health and of urban planning policies, which need to address urban growth in a more comprehensive manner. Firstly, in order to get a more accurate picture, assessments of the current situation need to also integrate non-numeric data and the level of satisfaction of the inhabitants with sanitation provision needs to be taken into account. Secondly, regular follow-up needs to pursue the implementation of sanitation infrastructures, so as to limit bias in statistical indicators. And thirdly, important large-scale measures need to be put in place to improve the sanitary conditions of Dakar's inhabitants.

On the other hand, behavioral factors, had a notable impact which was separate from that of socio-economic determinants. This means that interventions specifically targeting health literacy, which are less costly and easier to implement than broader education campaigns, can significantly reduce the burden of this type of infections. Although such interventions have been undertaken, some using children as "messengers", they generally targeted a specific disease, such as malaria (Ayi et al. 2010). In contrast, a more comprehensive set of measures to ensure better capacity to search and understand basic health information, as well as to make optimal decisions based on this information, could have wider benefits in the longer term.

Of course, the caveat with transposing this into public health policies is that, while knowledge can be acquired, domestic hygiene and vector protection also depend on individual and family choice (Borooah 2004). However, it seems reasonable to assume that, if individuals genuinely comprehend the health outcomes associated with their actions, given the importance that families generally place on the health of their offspring, they would be inclined to adopt health-promoting conducts which can be integrated into their

lifestyles.

Overall results also indicate that there is a relationship between the presence of mosquitoes in the area and the use of mosquito nets. However, as the qualitative analysis pointed out, people tend to only protect themselves against mosquito bites at night-time or when going to bed, so as to avoid having their sleep disrupted by mosquitoes. This indicates a lack of a more profound understanding of the ultimate goal and function of mosquito nets. Therefore, it may be more useful to slightly reframe LLITN-distribution campaigns, so as to encourage individuals to use nets even when there don't appear to be any mosquitoes in the area and even when they don't feel mosquito bites. More precise indications, such as clearly delineated time intervals when individuals should either use bed nets or another form of mosquito-bite prevention, could also prove useful. Since mosquito nets are relatively prone to wear and tear and thus become ineffective, insisting on the fact that individuals should regularly inspect and either mend or replace their nets when necessary is also crucial. Another, although slightly more costly intervention would be to provide either replacements or mending services, for low fees, thus ensuring proper usage. Finally, it could be useful to address the issue of older children, who seem to face additional risk of mosquito-borne diseases in areas of high mosquito densities. Since these children are more likely to be awake and possibly outdoors until later hours, it could be useful to better investigate additional protective measures for these age categories.

In terms of sanitation, the quantitative analysis showed that while the relative effects at the neighborhood area were limited, especially when compared to the individual level, the fixed effects associated with the perceived quality of sanitary infrastructures significantly affected the odds of mosquito-borne diseases.

Two aspects arise from this finding. The first one, from a more abstract perspective, is that interventions to improve sanitation (especially sewerage) at the area level, because they affect large numbers of people, can have an important role in reducing the healthcare burden of water-related diseases.

The second one is precisely the role of using the perceptions of beneficiaries as proxy for the quality of infrastructures: the present

study has pointed out that, in contexts such as the one of Dakar, where statistical indicators may not convey a comprehensive image of the population's living conditions, it may be useful to base the assessment of unmet needs primarily on the satisfaction of the inhabitants, than on classic indicators related to improved water sources or sanitation.

Moreover, the case of neighborhoods like Fith Mith and Soprim illustrates that public policies need to take into account not only the situation in the area considered, but also the effects of occurrences and situations in nearby areas: while Soprim was affected by mosquitoes from a pond located just outside its borders, Fith Mith was affected by floods of wastewater draining from the septic tanks located in neighborhoods uphill. Drawing on that, it appears that special attention needs to be paid to areas and neighborhoods which lie downhill of a slope or in a basin. In cities like Dakar, where the rainy season is short but forceful, abundant amounts of rainwater (which may sometimes mix with wastewater or solid waste) pool up and cause floods. Moreover, given the information provided by the qualitative analysis, it seems that there is a real need for sanitary education campaigns directed at those households located uphill on slopes, all while focusing on improving the quality of the sewerage infrastructure downhill.

Another aspect revealed by the interviews was that seasonal canals – whose function is to drain excess rainwater during the short wet season – are often clogged due to solid waste being thrown in during the long dry season and consequently overflow. A measure already put in place for one canal in Dalifort, to enclose the parts of the canal where trash usually gets dumped, could prove useful in other areas of Dakar as well. Since solid waste is thrown in these canals both by residents of the nearby areas and by passers-by, it could also prove useful to install garbage bins (present elsewhere in Dakar, although not in large numbers) alongside the canals and to educate inhabitants living in the vicinity of the canal to refrain from using the public garbage bins to dispose of household waste.

From a more general perspective, the qualitative component of this study has underlined a particular situation with which Dakar, as possibly other large West African cities, is faced. On the one hand, interviewees highlighted that life in a large city has changed the

ways people interact and loosened the ties between neighbors, compared to rural areas. On the other hand, both the ACTU-PALU community survey and the interviews have brought to light several failures of basic infrastructures, malfunctions which are often missed by the city's administration. In this context, Dakar's inhabitants are faced with the conjoined impact of both an insufficiently robust welfare state and of weaker social ties, which would normally constitute the additional "safety net" in villages.

To sum up, data used by the present study suggest that policies aiming for a reduction of water-related morbidity in children from large urban contexts from Sub-Saharan Africa, such as is the case of Dakar, need to have a twofold focus. Thus, they need to integrate on the one hand public policies to provide more reliable clean and improve the quality of sanitation and on the other hand more in-depth health literacy campaigns, which go beyond fragmented actions with specific messages and which aim to raise the general level of understanding and awareness in the general population, rather than targeting only those categories most at risk.

Consequently, articulating both sanitation/clean water measures with measures aiming to improve health literacy in a comprehensive and profound way are necessary, as investing in one without investing in the other will probably not lead to significant reductions of infectious disease morbidity for children in Sub-Saharan African contexts.

This is in line with some studies performed on Western contexts, looking at the decline of mortality from infectious causes in urban contexts at the end of the 19th and first half of the 20th centuries (D. Cutler and Miller 2005). There, although campaigns to promote healthy behavior slightly preceded large-scale public health measures and although a reduction in mortality had already begun before these clean water, sanitation and waste management interventions took place, the major drop was most likely the result of a synergy between the two. These refinements in private health behaviors also made it possible for the effects of public health technologies to increase over time (D. Cutler and Miller 2005). On that account, improving access to water and sanitation needs to be attended by private hygiene and protection measures, in a biomedically appropriate perspective. However, as Dos Santos (2011) points out, at

present this appears to not be the case for several African populations. Consequently, in order to better address this aspect, health literacy-oriented campaigns need to be grounded on research using not only quantitative data, but also qualitative one. This would allow to better understand the current representations of health and disease and would provide a more relevant starting point for such campaigns.

14.2 Research Perspectives

Given the limitations of the present study, a series of more refined research is desirable, to further explore the inter-relationships between behavior, environment and water-related illnesses in children. More precisely, in my analyses, both behavioral and environmental factors seem to play a substantial role in determining whether or not a child will suffer from a water-related infection. While behavioral factors are generally only assessed at the individual or family levels, environmental ones may refer to either the dwelling or the area (or even higher up, at the larger geographical area or climate level). The main issue with this is disentangling what pertains to the household and what pertains to the neighborhood, as the fact that one characteristic spreads across several levels of analysis, with “dynamic interactions within and between levels, is a challenge in the investigation of “neighborhood” effects as it is for epidemiology generally” (Diez Roux 2001, p.1787). Moreover, in most data available so far, measurement of this aspect is generally not without flaw, so I reckon this is the area which can most benefit from additional research, to better investigate the impact of each layer of the environment.

In terms of symptom evaluation, albeit costly, studies using data on both fever (declared) and parasitemia would provide a fully comprehensive image of mosquito-borne febrile illnesses.

In order to mitigate for the sometimes biased statistical indicators on access to water and sanitation in a given area, this research used a combination of variables estimating coverage, perceived quality and more in-depth interviews on the topic. Nevertheless, in terms of quantitative data, the perceived quality was measured at the neighborhood level, meaning there was only one opinion recorded

for the entirety of the neighborhood. However, it may not be shared by all households in the area, so additional data on this topic would be useful to better gauge the overall living conditions for each neighborhood.

More in-depth qualitative studies on secondary childcare practices in Dakar are also needed, so as to assess typical childcare activities of the nanny or other women in the household, as well as the average time spent by each of the carers with the child per day.

Additional, more detailed information on the usage of mosquito nets seems to be necessary, so as to provide a better starting point for LLITN distribution campaigns. For instance, assessing the state of mosquito nets used by those who declare using them as protection would allow to more accurately approximate user error and the real efficiency of LLITNs in the longer term. Another aspect worth investigating is that of older children, who potentially stay up later and thus are at increased risk of mosquito bites in areas of high mosquito densities, despite the use of bed nets. A more in-depth, qualitative investigation of the lifestyle patterns of these age categories could prove useful in better understanding and addressing the specific risks they face.

Given the amount of interdependencies across neighborhoods revealed by the qualitative analysis, it would also be desirable to have qualitative data, at the same time, on both the neighborhoods where the “cause” of an event takes place and on those where the “effects” are being felt. This would imply to broaden the analysis to neighboring areas and to analyze to what extent the environment of one neighborhood has an impact on the sanitation and general conditions of the ones in its vicinity. Along this line of thought, it would be useful, for example, to interview households located in the HLM area, uphill from Fith Mith, about the financial or logistic challenges they face, as well as the strategies they adopt to dispose of wastewater. Conversely, since Unité 8 was located relatively uphill on a slope, it would be interesting to research its neighboring areas located on the bottom of the slope, such as Unité 11, to judge whether or not they are affected by the same issues (overspills and floods) as the inhabitants of Fith Mith.

To sum up, I believe that there is a real need for more research

offering both a quantitative and a qualitative perspective in the field of infectious diseases in general. The two approaches are not incompatible, as it was considered until recently (Bryman 2004a). They are complementary and not only in the sense that they offer different views of the same phenomenon, but also in the sense that triangulating research methods mitigates for the specific bias which is inherent to each of them (Randall and Koppenhaver 2004; Small 2011). Findings are hence strengthened, as the results of each genre either corroborate or complete each other (Miles et al. 2012). Thus, better articulation between statistical and non-numeric data, as the present research has pointed out, would likely yield a better understanding of the complex web of determinants in childhood infections.

APPENDICES

Appendix A

Factors for water-related diseases in existing literature

Sphere	Determinant	Outcome	Study
Demographic	Age	Health & mortality	(Simon et al. 2015) (Ngure et al. 2013) (Shope 2014)
		Diarrhea	(Kandala, Magadi, et al. 2006) (Kandala, Emina, et al. 2009) (Monteverde et al. 2010) (Siziya et al. 2013)
		Fever	(Kandala, Emina, et al. 2009)
		Malaria	(Imbert et al. 1997) (Mauny et al. 2004) (Thang et al. 2008)
		Co-morbidity	(Kazembe and Namangale 2007) (Yadav 2017)
	Sex / gender	Health & mortality	(Buvinić et al. 2006) (Muenchhoff and Goulder 2014) (Green 1992) (Mitra et al. 2000) (WHO 2007)
		Diarrhea	(Siziya et al. 2013) (Kandala, Emina, et al. 2009)
		Fever	(Kandala, Emina, et al. 2009)
		Dengue	(Anker and Arima 2011)

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Sphere	Determinant	Outcome	Study
Socio-economic	Breastfeeding status	Health & mortality	(Mané et al. 2006) (Mosley 1984) (K. B. Simondon and F. Simondon 1998)
		Malaria	(Vora et al. 2010)
	Mother's age	Health conduct	(Tamis-Lemonda et al. 2002) (Ansari 2011)
		Diarrhea	(Al Ayed 2010) (Kandala, Magadi, et al. 2006) (Kazembe, Muula, et al. 2009) (Mbugua et al. 2014)
		Fever	(Kazembe, Muula, et al. 2009)
	Mother's education	Health & mortality	(Behrman and Wolfe 1987) (Cochrane et al. 1982) (Hobcraft 1993) (Mosley and Chen 1984) (Palloni 2006)
		Health conduct	(Noor et al. 2006)
		Diarrhea	(Dargent-Molina et al. 1994) (Einstein et al. 2017) (George et al. 2014) (Kandala, Magadi, et al. 2006) (Mbugua et al. 2014) (Siziya et al. 2013)
		Fever	(Filmer 2005)
		Malaria	(A. Diallo, Dos Santos, et al. 2012) (Koram et al. 1995a) (Krefis et al. 2010) (Nyarko and Cobblah 2014)
	Mother's occupation	Health conduct	(Desta et al. 2017)
		Diarrhea	(Elizabeth and Raj 2012) (Mihrete et al. 2014) (Thiam et al. 2017)
	Family wealth	Health & mortality	(Mosley and Chen 1984) (Palloni 2006)
		Diarrhea	(Kandala, Emina, et al. 2009) (Kandala, Ji, et al. 2007) (Woldemicael 2001)
		Fever	(Kandala, Emina, et al. 2009) (Kandala, Ji, et al. 2007) (Yusuf et al. 2010)
		Malaria	(Nyarko and Cobblah 2014) (Thang et al. 2008)
		Dengue	(Demanou et al. 2014)

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Sphere	Determinant	Outcome	Study
Behavioral	Anti mosquito measures	Fever	(Yusuf et al. 2010)
		Malaria	(Clarke et al. 2002) (Guthmann et al. 2001) (Keiser et al. 2005) (Konradsen et al. 2003) (Matthys et al. 2006) (Mauny et al. 2004) (Nahum et al. 2010) (Pullan et al. 2010) (V. Robert et al. 2003) (Rose-Wood et al. 2010) (Snow et al. 1998) (Sullivan 2010) (Tolle 2009)
		Health conduct	(Dos Santos and LeGrand 2007) (Jalan and Ravallion 2003) (Waddington et al. 2009)
		Diarrhea	(Abu Mourad 2004) (Borooah 2004) (Bukonya and Nwokolo 1990) (Contzen et al. 2015) (Fewtrell and Colford 2004) (Heller 1999) (Masangwi et al. 2009) (Moraes et al. 2003) (Myaux et al. 1997) (Rego et al. 2005) (UNICEF and WHO 2009)
		Malaria	(Koram et al. 1995b) (Peterson et al. 2009)
Environmental	Access to water	Health & mortality	(Dos Santos and LeGrand 2007) (Fewtrell and Colford 2004) (A. J. Pickering and Davis 2012) (Timaues and Lush 1995)
		Diarrhea	(Al Shammari et al. 2001) (Dos Santos, Ouédraogo, et al. 2015) (Fewtrell and Colford 2004) (Girma et al. 2008) (Heller 1999) (Jalan and Ravallion 2003) (Masangwi et al. 2009) (Moy et al. 1991) (A. J. Pickering and Davis 2012) (Seigel et al. 1996) (Timaues and Lush 1995) (UNICEF and WHO 2009) (Waddington et al. 2009) (WHO 2013a)
		Malaria	(Koram et al. 1995b) (Matthys et al. 2006)
		Dengue	(Aziz et al. 2012) (Braga et al. 2010) (Dieng et al. 2012)

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Sphere	Determinant	Outcome	Study
Household sanitation			(Padmanabha et al. 2010)
			(Ridde et al. 2016)
		Co-morbidity	(Yadav 2017)
		Health & mortality	(Fahrmeir and Khatab 2008)
		Diarrhea	(Al Shammari et al. 2001)
			(Burki 2015)
			(Evans and Haller 2005)
			(Fewtrell and Colford 2004)
			(Girma et al. 2008)
			(Heller 1999)
			(Masangwi et al. 2009)
			(Monteverde et al. 2010)
			(Moraes et al. 2003)
			(Moy et al. 1991)
			(Myaux et al. 1997)
Household waste			(Norman et al. 2010)
			(Okullo et al. 2017)
			(Rego et al. 2005)
			(Seigel et al. 1996)
			(Timaeus and Lush 1995)
			(Waddington et al. 2009)
			(WHO 2019b)
			(WHO 2017b)
			(UNICEF and WHO 2014)
			(Woldemicael 2001)
		Fever	(Yusuf et al. 2010)
		Malaria	(Pullan et al. 2010)
		Dengue	(Dieng et al. 2012)
			(Tsuzuki et al. 2009)
		Co-morbidity	(Yadav 2017)
Crowding		Health & mortality	(Dos Santos and LeGrand 2007)
		Diarrhea	(Heller 1999)
			(Rego et al. 2005)
		Malaria	(Machault et al. 2009)
		Dengue	(de Mattos Almeida et al. 2007)
			(Hayden et al. 2010)
			(Sutherst 2004)
		Health & mortality	(Osborn 1998)
		Diarrhea	(Masangwi et al. 2009)
			(Seigel et al. 1996)
			(Woldemicael 2001)
		Malaria	(Ghebreyesus et al. 2000)
			(Konradsen et al. 2003)
			(Koram et al. 1995b)
			(S. W. Lindsay, Emerson, et al. 2002)
			(V. Robert et al. 2003)
			(Yamamoto et al. 2010)
		Dengue	(Braga et al. 2010)

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Sphere	Determinant	Outcome	Study
		Co-morbidity	(Kazembe and Namangale 2007)
	Dwelling type	Diarrhea	(Moraes et al. 2003) (Moy et al. 1991) (Ngure et al. 2013) (Rego et al. 2005) (Yaya et al. 2018)
		Fever	(Deressa et al. 2007)
		Malaria	(Ghebreyesus et al. 2000) (Guthmann et al. 2001) (Konradsen et al. 2003) (Koram et al. 1995b) (Koram et al. 1995a) (S. W. Lindsay, Emerson, et al. 2002) (Matthys et al. 2006) (Snow et al. 1998) (V. Robert et al. 2003) (Yamamoto et al. 2010)
		Dengue	(Demanou et al. 2014)
	Livestock	Health & mortality	(H. Pickering et al. 1986)
		Diarrhea	(Rego et al. 2005)
		Malaria	(Ghebreyesus et al. 2000) (Hasyim et al. 2018) (Koram et al. 1995a) (S. W. Lindsay, Emerson, et al. 2002) (Peterson et al. 2009)
		Dengue	(Dieng et al. 2012)
	Waste collection	Diarrhea	(Heller 1999) (Monteverde et al. 2010) (Muñoz-Cadena et al. 2009) (Rego et al. 2005) (Santamaria and Toranzos 2003)
		Malaria	(Awolola et al. 2007)
		Dengue	(Hayden et al. 2010) (de Mattos Almeida et al. 2007) (Sriptom et al. 2010)
	Sewerage	Diarrhea	(Barreto et al. 2007) (Berendes et al. 2018) (Fewtrell and Colford 2004) (Heller 1999) (Moraes et al. 2003) (Norman et al. 2010)
		Dengue	(Braga et al. 2010)
	Proximity to water	Fever	(Deressa et al. 2007)
		Malaria	(Clarke et al. 2002) (Fobil et al. 2012) (Ghebreyesus et al. 2000) (Guthmann et al. 2001) (Keiser et al. 2005) (Konradsen et al. 2003)

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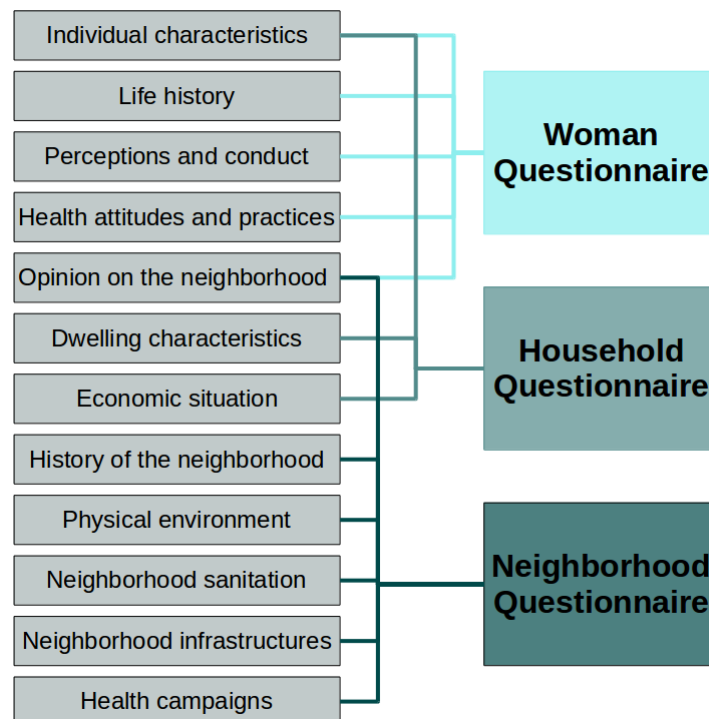
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Sphere	Determinant	Outcome	Study
Climatic			(Koram et al. 1995b)
			(Matthys et al. 2006)
			(Nahum et al. 2010)
			(Peterson et al. 2009)
			(Pullan et al. 2010)
			(V. Robert et al. 2003)
			(Salem 1998)
			(Staedke et al. 2003)
			(Sutherst 2004)
			(Yamamoto et al. 2010)
		Dengue	(Arunachalam et al. 2010)
			(Braga et al. 2010)
			(de Mattos Almeida et al. 2007)
	Temperature	Diarrhea	(Hashizume et al. 2007)
			(Huq et al. 1984)
			(National Research Council 2001)
			(Reyburn et al. 2011)
			(Singleton et al. 1982)
			(Teshima et al. 2004)
		Malaria	(Béguin et al. 2011)
			(Chaves and Koenraadt 2010)
			(Malakooti et al. 1998)
			(Patz and Reisen 2001)
	Precipitation	Diarrhea	(Rogers and Randolph 2000)
			(Sankoh and Ye 2011)
			(Deubel and Rodhain 1999)
			(Hales et al. 2002)
			(Hayden et al. 2010)
			(Padmanabha et al. 2010)
			(Rowley and Graham 1968)
		Malaria	(Hashizume et al. 2007)
			(National Research Council 2001)
			(Reyburn et al. 2011)
	Altitude	Malaria	(Béguin et al. 2011)
			(Malakooti et al. 1998)
			(Sankoh and Ye 2011)
		Dengue	(Aziz et al. 2012)
			(Arunachalam et al. 2010)
			(Deubel and Rodhain 1999)
			(M. Diallo, Ba, Sall, et al. 2003)
			(Rowley and Graham 1968)
		Malaria	(Chaves and Koenraadt 2010)
			(Malakooti et al. 1998)
			(Patz and Reisen 2001)

Note: The “Malaria” and “Dengue” categories also include studies regarding the mosquito species transmitting the diseases.

Appendix B

Themes in the ACTU-PALU Questionnaires



Appendix C

Interview Structure

Preamble

- Making acquaintance: The interviewers greet the interviewees, present themselves and thank the interviewees for accepting to be interviewed and for their time
- Presentation of the study: The interviewers present the research theme and objectives, mentioning that the interview is part of a research project on child health, funded by the Belgian Fonds de la Recherche Scientifique. The research aims to understand the manner in which the immediate environment (street, neighborhood) and behaviors/actions interrelate, as well as the role of these aspects in child health.
- Confidentiality: The interviewers reassure the interviewees that the interview is strictly confidential and vouch to respect anonymity. Recording of the interview is suggested, strictly in the purpose of facilitating the flow of the discussion (as opposed to writing down the answers) and to avoid error in note-taking. The interviewees are informed that, should they wish to receive it, the interview recording can be sent to them.
- Duration: The duration of the interview should not exceed

an hour and a half.

- Reassurance of the interviewees: The interviewers insist that there is no correct or wrong answer, but that they are interested in finding out the personal experience of the interviewees.

General Interview Guide

1. The Neighborhood

- Background

Since when have you been living in this neighborhood? And before that, were you living in another neighborhood of Dakar? Which one?

In the area where you live, are there water bodies or groves? Could you describe them for me a little?

In general, are there floods in the neighborhood during the rainy season? If so, could you tell me how long they usually last and if/how they affect your daily life?

Overall, do you consider the neighborhood to be rather clean or rather dirty? For what reason(s)?

- Infrastructure

What are your experiences regarding access to water in this neighborhood? Does your household use the general piped water network?

What is your opinion on the quality of drinking water? And on water cuts? On the price of water? How do these aspects influence your consumption? (For example, does it arrive that you use less water than you would need?)

What do you think of the wastewater and household waste management service in the neighborhood? Does your household use these services? If not, how

do you clear wastewater and household waste? And where?

- Neighbors

What is your opinion about your current neighbors?

Do you sometimes chat with some of your neighbors (more than a minute or two) when you meet? If yes, what are the topics you usually talk about? Does it happen that you exchange information regarding children? For example?

2. Prophylaxis

- Mosquitoes

In your opinion, are there more or fewer mosquitoes in this neighborhood, compared to other ones in Dakar?

Are there periods of the year when you notice more mosquitoes?

Do these mosquitoes mainly bite during the day or in the evening?

To your knowledge, do your neighbors take measures to avoid being bitten?

How about you and your family, do you use certain means to avoid mosquito bites? For what reason(s) yes/no? If only part of the family does, what members do and why?

Do you sometimes discuss with your neighbors about these aspects? If so, could you detail a bit on this?

Do you have family or friends in other neighborhoods of Dakar? If yes, what do you know about their experiences with regard to mosquitoes?

- Hygiène

What kind of water do you use for drinking (where do you get this water from)?

Do you do anything to this water before drinking it? What?

How and where do you store drinking water in the household?

How and where do you store the household waste?

When you eat raw fruit or vegetables, do you do anything to them before eating them?

3. Children

How many children live in this household and how old is each of them?

(For each child:)

Do the parents of <child> live in the household? Do they work? In the household or outside?

At home, who spends the most time with <child>?

If <child> has, for example, diarrhea, fever or a cough, who in the household takes care of it? What will the person generally do?

4. Nanny / Maid

Is there someone whom you pay to help you with household chores? *(If not, insist, whether there is a cousin, etc. from the countryside, who helps in the household.)*

Does this person live under the same roof with you?

Is she a (distant) relative?

How old is she?

Did she go to school? If yes, what schooling level did she reach?

Does she also care for any of the children? What does she do for the children? Approximately how much time does she dedicate to the children, per day or per week?

5. Socio-demographic characteristics

How many people live in this dwelling?

How old are you?

Did you go to school? If yes, what is the highest level of schooling that you finished?

Do you do paid work or have you done paid work in the past? If yes, in what field?

6. Thank you for your time!

Appendix D

Summary of Interviewees

ID	Name	Age	Gender	Neighborhood
1	Selbé	60	F	Dalifort
2	Fadima	56	F	Dalifort
3	Combé	22	F	Dalifort
4	Idrissa	59	M	Dalifort
5	Aminata	35	F	Fith Mith
6	Safiétou	42	F	Fith Mith
7	Adja	26	F	Unité 8
8	Abdoulaye	62	M	Unité 8
9	Sawdiatou	25	F	Unité 8
10	Mame	55	F	Fith Mith
11	Fatoumatou & Binta	60 & 24	F & F	Fith Mith
12	Coura	27	F	Soprim 1
13	Khadija	19	F	Soprim 1
14	Niouma	60	F	Soprim 1

Note:

Names have been changed.

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