Environmental Threats and Childhood Fever during the Rainy Season in Dakar-Senegal: Results from Hierarchical Models

Stephanie Dos Santos[1], Iulia Rautu[1], Jean-Yves Le Hesran[2], Mody Diop[3], Abdou Illou Mourtala[4], Alphousseyni Ndonky[5], Richard Lalou[6]

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[1] Institut de Recherche pour le Développement, Laboratoire Population-Environnement-Développement, BP 1386, Dakar, Senegal.

[2] Institut de Recherche pour le Développement, Unité mère et enfant face aux infections tropicales, Faculté de pharmacie, Laboratoire de parasitologie, 4 avenue de l'Observatoire, 75270 Paris cedex 6, France.

[3] Agence Nationale de la Statistique et de la Démographie, BP 116, Point E, Dakar, Senegal.

[4] Ecole Nationale de la Statistique et de l'Analyse Economique, BP 45512, Fann, Dakar, Senegal.

[5] Département de Géographie, Université Cheikh Anta Diop, Fann, Dakar, Senegal.

[6] Institut de Recherche pour le Développement, Laboratoire Population-Environnement-Développement, Université de Provence, 3 place Victor Hugo, 13331 Marseille cedex 03, France.

Corresponding author : Dr Stephanie Dos Santos, Institut de Recherche pour le Développement, Laboratoire Population-Environnement-Développement, BP 1386, Dakar, Senegal. Stephanie.DosSantos@ird.fr

Introduction

In sub-Saharan Africa, a major cause of childhood fevers are water-borne diseases, such as typhoid, or water-related diseases, in particular mosquito-borne pathogens such as malaria, dengue and other arboviral diseases. Such diseases account for approximately 17% of the estimated global burden of infectious diseases (WHO 2004). Due to the rapid and unplanned urbanization, these diseases represent a substantial public health concern (Robert et al. 2003).

Numerous factors play a part in child health differentials. These are manifested at the individual level (Wagstaff et al., 2001). But other contextual factors should be considered when investigating the associations of disparities with health outcomes (Holmes et al. 2008, Merlo 2003), and neighborhood effects in particular (Subramanian 2004). Long before, Mosley and Chen (1984) were among the first to theorize environmental factors such as intermediate biomedical factors affecting child mortality, named `proximate determinants'.

The occurrence of childhood fever is particularly a multifactorial process, related to people, to the household and to the environmental neighbourhood where the child lives. In Sub-Saharan Africa, although numerous cases of fever in children during the rainy season are caused by vectors, the web of determinants for those fevers is still a complex one. The relative contribution of each factor varies, as a function of complex interactions between environmental characteristics pertaining to both the household level and the neighborhood level.

At the household level, aspects related to house construction quality and salubriousness or protective measures may favor or impede vector presence. Such aspects as openings, unscreened windows and eaves can facilitate the entering of mosquitoes inside the compound, while cracks and crevices in walls serve as hiding places (S. W. Lindsay et al., 2002; Konradsen et al., 2003; Robert et al., 2003; Yamamoto et al., 2010; Yusuf et al., 2010). Characteristics referring to salubriousness also play an important role, by means of water storage inside the compound (Tsuzuki et al. 2009). The role of protective measures is somewhat disputed. On the one hand, protective measures in general – and long-life treated insecticide nets in particular – have long proven their efficiency (Snow et al. 1988). On the other hand, studies have shown that the use of such measures is highly dependent of mosquito nuisance, which is a function of the vector’s density (Thomson et al. 1994; Chavasse et al. 1996; K. Yohannes et al. 2000). Therefore, the use of protective measures is not equally distributed in the whole population, also due to socio-economic and cultural factors (Ng'ang'a et al 2008; Adongo et al 2005).

At the neighborhood level, the presence of wetlands in the area is among the chief factors which increase the risk of mosquito-borne diseases. Ponds, flood plains can also favor vector reproduction since they constitute stagnant waters. Such wetlands may be either natural or man-made, though the former are less prevalent in urban areas. Market-gardens equipped with wells, constitute a favorable environment for mosquito larvae (Pages et al. 2008; Robert et al. 2003). Urban farming can also favor vector reproduction, by means of the man-made water bodies used for irrigation (Ghebreyesus et al. 2000; Matthys et al. 2006; Van Benthem et al. 2005). Mosquitoes have been found to breed successfully in (fish) ponds, flood plains and irrigated fields, since they constitute stagnant waters (Elston 2005; Keiser et al. 2005; Peterson et al. 2009). If present, natural wetlands – such as swamps and streams – also increase the risk of disease (Matthys et al. 2006; Robert et al. 2003; Staedke et al. 2003).

Studies performed by conventional single level analytical methodologies have been seriously criticized, primarily because they fail to consider the existence of a multilevel structure when analyzing childhood fever in different environment (that is children nested in household, nested in neighborhood). Single level analyses underestimate statistical uncertainty and lead to inappropriate conclusions, providing an unsuitable basis for decision making. A single level analysis is unable to discern whether the observed variation in childhood fever is attributable to individual differences between children, or to the influence of environmental factors related to both the household level and the neighborhood level. Multilevel analysis is today considered a more appropriate way to monitor environmental health, as it allows a less biased estimation of uncertainty, and can also separate and quantify contextual effects (Chaix et al. 2005; Diez-Roux 2001).

It is thus clear that urban mosquito-borne fevers are highly diverse, both in terms of transmission and prevalence, and cases tend to cluster near mosquito breeding sites (Peterson et al. 2009; Staedke et al. 2003; Sutherst 2004). Even though previous authors have already shown the theoretical existence of a relationship between environmental threats and child health, the complex processes underlying this association still remain poorly highlight by empirical evidence, in Africa in particular. Apart from the individual and household characteristics, environmental factors at both the household and the neighborhood level can have an influence on those fevers especially during the rainy season. The objective of this paper is to identify environmental threats associated with fever occurrence in children in Dakar using a multi-level approach. Dakar, the capital city of Senegal ranked 155th out of 183 countries according to the Human Development Index (UNDP 2011), is particularly interesting from this point of view. The climate is hot with a short rainy season and very low annual rainfall. In addition, due to both rapid population growth and the increasing prevalence of individual houses, Dakar experiences a rapid expansion of its urban space (ANSD 2010), especially in suburban area, leading to a significant social and environmental heterogeneity. This spatial expansion in the suburbs was made and continues to be made in areas that were traditionally wetlands, creating a large heterogeneity in the environment, with green areas or floods during the rainy season (Mbow et al. 2008). In terms of vector-borne diseases, Diallo and colleagues (2012) showed that a risk of malaria transmission and a parasitological prevalence are variable but very significant in certain neighborhoods of Dakar, especially in the suburbs.

After presenting the conceptual framework, the contexts are described. We briefly discuss the data and the statistical methods used before presenting the results. Finally, we discuss the limitations of our approach as well as future developments for its improvement.

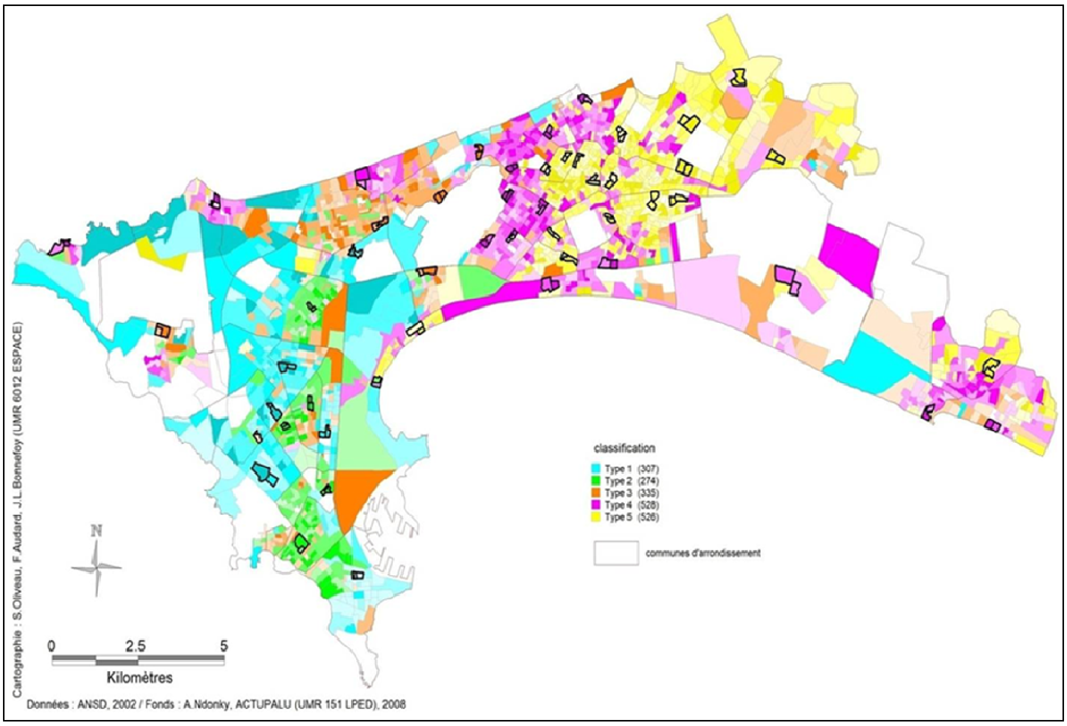
Methods

Data collection

Data come from the Actu-Palu project, a cross-sectional study population. Following the model of household surveys using the IRIS (Grouped Islets for statistic indicators) carried out within the SIRS research program (health, inequalities and social breakdown in France) (Parizot et al 2004), almost 3,000 households were surveyed within 50 neighborhoods from the metropolitan area during the 2008 rainy season (from October to December).

The selection of study sites was made to highlight the socio-economic and environmental heterogeneity of the urban zone. The objective was to survey homogeneous zones and the most heterogeneous zones between them. A classification by dynamic clusters (K-means method), using census variables belonging to the same topic (housing, household equipments, sanitation) selected from a principal component analysis, identify 5 types of census area (DR for *district de recensement*) (ANSD 2010). These types ranked DR from high to low living conditions. The most representative type of each neighborhood was chosen. 42 DR were randomly chosen. To reach the number of 50 sites planed for the study, 8 other DR were then added according their proximity to swamp in order to consider the environmental effect. Finally, to avoid the risk of insufficient number of eligible households in one DR, each DR was paired with the nearest same type DR, thereby representing one neighborhood (Figure 1).

Figure 1 – Map of the survey sites, Actu-Palu project, 2008, Dakar, Senegal



To be eligible, a household must contain at least one child aged 2-10 years old. A person responsible for the household answered a standard pre-coded questionnaire based on socioeconomic, housing and close environmental conditions and the occurrence of recent fever for each child of the household. We excluded fevers caused by mumps, cuts or toothaches during the survey. The data covered 7,400 children.

Key independent variables

Household environmental variables

Household environmental characteristics were assessed by asking household respondents questions about having a least piped water in the dwelling (or not), a wastewater management (sewer or septic tank versus other) and a solid waste management (a collecting system versus throw outside). In addition to water and sanitation factors, mosquito protective measures uses were surveyed and categorized in three modalities in the statistical analysis: at least mosquito nets for beds and/or windows, other measures such as burning mosquito coils or traditional incense and none of them. The first modality was considered to be the most effective measure.

Neighborhood environmental variables

Neighborhood characteristics and potential environmental factors for disease were assessed by a community questionnaire that comprises eight sections, adressing physical characteristics, salubriousness and spraying campaigns. As in most community surveys, the respondents were interviewed in groups. This method is recognized to improve data quality (Schoumaker et al, 2006; Frankenberg, 2000).

Groups of discussion were composed by the neighborhood headman (the traditional neighborhood authority), the neighborhood representative (which represents the neighborhood in administrative matters) and a wide range of profiles in terms of sex, age and profession. The choice was largely left to the neighborhood headman who had been briefed by the interviewers about the type of respondent to be selected. On average, the group was constituted by seven respondents per neighborhood, with a minimum of four and a maximum of eleven respondents.

The community questionnaire was composed by a majority of closed questions, recommended for collecting data comparable over district (Bilsborrow, 1984). It comprised eight sections; the first focusing on basic information about the respondents and the other covering several topics such as the history of the settlement, physical characteristics and salubriousness, infrastructures, health and social services, accessibility and transport links, neighborhood groups and associations, spraying campaign. In general, finding respondents posed very few problems, except for some intensive discussions for certain questions. The average duration of each interview was a little over one hour and a half.

Neighborhood environmental characteristics were assessed by asking groups of discussion questions about the presence (or the absence) of a canal and wetlands. For those who answered positively, the seasonal (or the permanent) character was precised. The salubriousness of the neighborhood was measured by surving people about the presence of areas of floods during the rainy season, a wastewater system and a solid waste collecting system in the neighborhood. Groups were also asked if a spraying campaign had been implemented in the neighborhood to stifle the mosquitoes carrying malaria during the last year.

Considered health determinants

As well-known health determinants, the child’s age and sex, mother’s education, age and activity and the household’s wealth were included.

Child’s age was kept as a continuous variable to reduce possible residual confounding. Three mother’s age group was defined: “less than 30 years old”, “30-39” and “40 and over”. Mother’s education level comprised only two categories, given the low level of education: “no formal qualification - none” and “primary and over”. Mother’s employment status was categorized as “independent” (both in the formal or informal sector), “other job” including formal and informal employment, “housewife” because of the importance of this group (48% of the mother) and “other”.

For measuring relative wealth, a household asset indicator was constructed, based on possession of consumer durables (e.g. radio, television, video, sofa, air conditioning, fridge and ventilator). These assets likely provide household’s long-run economic status (Filmer and Pritchett, 2001) and perform as well as an indicator based on consumption (Wagstaff and Watanabe, 2003). The variable is continuous and represents the sum of each item possessed by the household. The indicator was then ranged from 0 to 7, as each item possessed is equal to one.

The household questionnaire and the community questionnaire were conceived to be factored into multilevel analyses since children are nested in households which, in turn, are nested in neighborhoods.

Data analysis

Multilevel modeling has provided attractive solutions, which is still not so common in tropical research on health. The usual analyses of the relationship between environmental factors and fever often treat the former at only one level, the household level or the neighborhood level. However, the exposure to environmental risk varies according to these two competing level.

Since our dependent variable is binary (individual were declared a fever or not), we used the logistic form of the multilevel model. A three-level modeling process was performed. Recent fever occurrence is modeled level by level according to individual, household and neighborhood levels. We then fitted six models in stages: model 1 was empty, without any independent variable, to calculate baseline variances of individual’s fever at 2nd and 3rd level. Model 2 incorporated child characteristics (sex, age) and socio-economic variables (mother’s education, age and activity and a wealth index). Model 3 contained just household-level environmental determinants (drinking water, wastewater management, solid waste management and mosquito protective measures). Model 4 adds child and socio-economic characteristics in addition to household-level environmental determinants. Model 5 included both environmental covariates at the neighborhood level (floods, shrub lands, water bodies, solid waste and wastewater management facilities) and child and socio-economic characteristics. Model 6 tested all individual-level, household-level and neighborhood-level variables simultaneously. All models were performed using MLwiN version 2.2. The fixed effect estimates were converted to odds ratios (OR) and significance levels were calculated.

The random effect was then analyzed. These methods allow consideration of within group (household and neighborhood) and between-group relations. The intraclass correlation allows calculation, on an empty model, of the proportion of the total variance explained by the grouping structure, in our case households and neighborhoods. The intraclass correlation (ICC) was estimate with the random effects, namely the variance respectively from household level and from neighborhood level. As suggested by Snijders and Bosker (1999) concerning a three level-model, two ICCs were calculated, in which the individual variance equal to $\Pi^2/3$ (3.29):

- ICC at household level: $\Omega_u = (\sigma^2_u+\sigma^2_v)/(\sigma^2_u+\sigma^2_v+ \Pi^2/3)$
- ICC at neighborhood level: $\Omega_v = \sigma^2_v/(\sigma^2_u+\sigma^2_v+ \Pi^2/3)$

where σ^2_u corresponds to the variance at the household level and σ^2_v to the variance at the neighborhood level.

Before estimating fixed and random effects, we analyzed some descriptive results, especially to sketch the urban heterogeneity in terms of environmental conditions. Geographic mapping analysis was performed by using MapInfo Version 9.0 for Windows.

Results

Environmental heterogeneity

The descriptive results based on the community questionnaire confirm that the agglomeration of Dakar is characterized by a great environmental heterogeneity. The issue of salubriousness is particularly revealing. Of the 50 neighborhoods surveyed, 39 declared to have problem with salubriousness (Figure 2). This perception varied substantially from one neighborhood to another, but the problem seemed to be worst in Pikine.

Figure 2 – Perception about the salubriousness in the neighborhood (Actu-Palu, 2008)

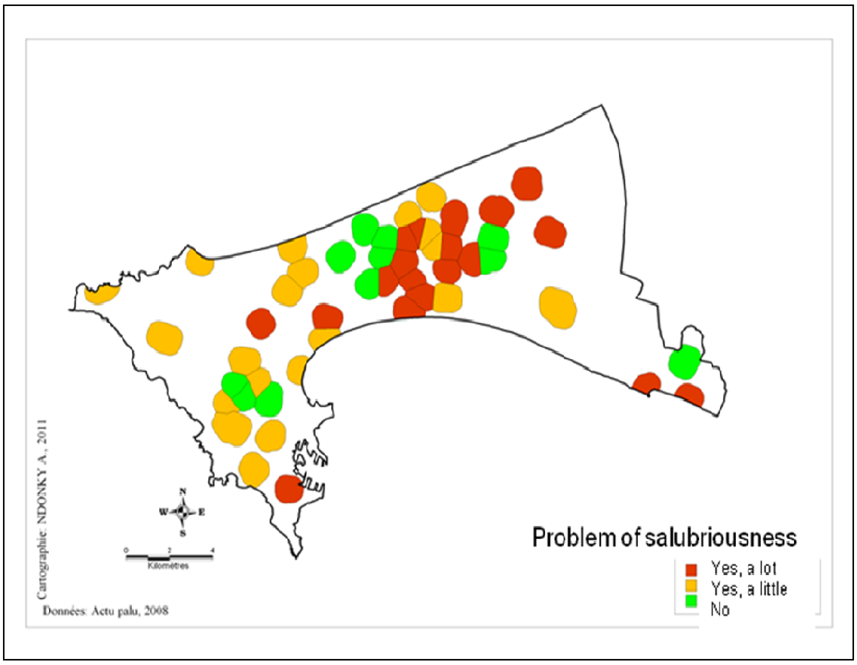
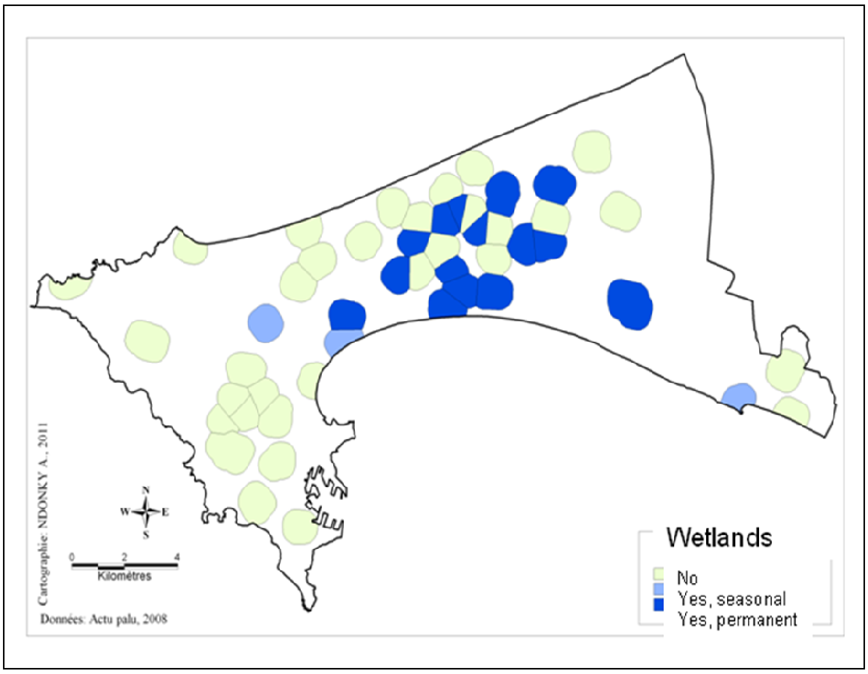


Figure 3 – Presence of water bodies/wetlands (Actu-Palu, 2008)



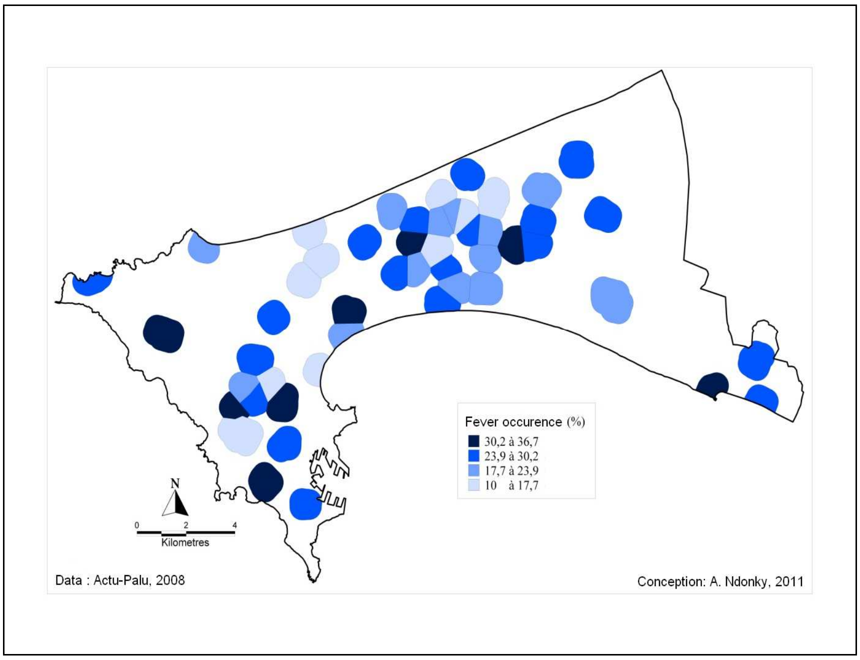
Concerning wetlands, of the 50 neighborhoods surveyed, 18 had some type of wetland. 32% of the children in our sample lived in a neighborhood with a permanent wetland and 6% lived in a neighborhood with a seasonal wetland. Practically all of these children resided in the suburbs of Dakar (figure 3).

Fever occurrence

The total population of this study was 7,293 children, nested in 2,948 households, of whom 1,742 (24%) had had a recent fever.

Rates of recent fever varied substantially from one neighborhood to another, ranging between 10 and 37% (figure 4). There was no concentration of high occurrences that were distributed all around the center as well as in the sprawl of Dakar.

Figure 4 –Child fever occurrence in Dakar in 50 neighborhoods



Multivariate results

The hierarchical organization of the data set in levels, fixed and random effects and cross-level interactions were then considered. The findings (table 1) indicate that the occurrence of fever was influenced by factors from all hierarchical levels.

Of the considered health determinants (model 2: individual-level and socio-economic household-level), being an older child and having a mother who was not independent in her job (other job) or was a housewife were associated with lower occurrences of fever. On the contrary, having a mother who was educated was associated with higher occurrences.

Of the household’s environmental factors (model 3), to throw outside the solid waste and to use a mosquito protective measures were associated with higher occurrence. Children who lived in a household where garbage pick-up was managed by a collecting system had less risk of a fever than children who lived in a household where garbage was thrown outside. Children who live in a house not using protective measures against mosquitoes were less at risk of fever than children who live in a house using protective measures. On the contrary, living in a house where wastewater was thrown outside was associated with lower fever occurrence.

Table 1 – Multilevel models with estimated fixed effects (odds ratios (OR) and significance levels) and random effects between the occurrence of child fever, considered household-level and neighborhood-level environmental variables and controlling for individual and socio-economic factors.

Fixed effects	**Model 1** OR	**Model 2** OR	**Model 3** OR	**Model 4** OR	**Model 5** OR	**Model 6** OR
Considered health determinants						
Child's bio-demographic variables						
Sex (male)						
Female		1.02		1.02	1.02	1.02
Age **(**continuous variable)		0.90***		0.90***	0.90***	0.90***
Household's factors						
Mother's age (< 30)						
30-39		0.99		0.99	0.99	0.99
40 and over		1.08		1.07	1.08	1.07
Mother's education (none)						
Primary and over		1.17**		1.15**	1.17**	1.16**
Mother's activity (independent)						
Other job		0.76**		0.76**	0.76**	0.76**
Housewife		0.85**		0.84***	0.85**	0.84**
Other		0.97		0.97	0.97	0.96
Wealth index (continuous variable)		0.99		0.99	0.99	1.00
Household's environmental factors						
Drinking water (piped water in the dwelling)						
Other			1.10	1.08		1.08
Wastewater management (sewer or septic tank)						
Other (throw outside)			0.83**	0.85**		0.82**
Solid waste management (collecting system)						
Other (throw outside)			1.38***	1.39***		1.39***
Mosquito protective measures (none)						
At least mosquito nets			1.83***	1.82***		1.72***
Others measures (no mosquito nets)			1.87***	1.85***		1.77***
Neighboorhood's environmental factors						
Canal (absence)						
Seasonal presence					1.87***	1.81***
Permanent presence					1.18	1.16
Wetlands - Niaye (absence)						
Seasonal presence					1.31	1.31
Permanent presence					1.22*	1.18*
Area of floods (absence)						
Presence					0.85	0.88
Wastewater system (absence)						
Presence					0.90	0.84
Solid waste collecting system (absence)						
Presence					0.94	0.91
Spraying campaign (no)						
Yes					0.86	0.86*
Random effects (standard errors)						
Variance *Ω* (SE)						
Household level (Ω_u)	0.43 (0.07)	0.46 (0.07)	0.42 (0.07)	0.45 (0.07)	0.46 (0.07)	0.45 (0.07)
Neighborhood level (Ω_v)	0.06 (0.02)	0.06 (0.02)	0.05 (0.02)	0.05 (0.02)	0.04 (0.02)	0.03 (0.02)
Intraclass correlation (%)						
Household level (Ω_u)	13.0	13.6	12.5	13.2	13.1	12.7
Neighborhood level (Ω_v)	1.59	1.57	1.33	1.31	1.06	0.80

Significance level: ***: p<0.01; **: p<0.05; *: p<0.10.
Reference category in parenthesis.

When household’s environmental factors and individual-level and socio-economic household-level characteristics (as potential confounders) were tested simultaneously (model 4), there were no significant changes in the results.

Results also highlighted the role of the presence in the neighborhood of wetlands and canals in the risk of childhood fever, when environmental factors at the neighborhood level were modeled with individual-level and socio-economic household-level characteristics (as potential confounders) (model 5). In particular, having a seasonal canal and having permanent wetlands in the neighborhood were associated with higher fever occurrences.

When environmental factors at the neighborhood level were modeled alongside considered individual-level, socio-economic household-level and environmental household-level factors (model 6), there were no changes in the results except for the effect of a spraying campaign: having such a neighborhood measure during the last year was negatively associated with the childhood fever occurrence.

Model after model, the stability of the most of household-level and neighborhood-level environmental results was also noteworthy.

The analysis of the random effects confirms that a part of the variation of the fever was associated to other than individual characteristics. In each model, the inter-household variance was greater than the inter-neighborhood variance. This was particularly the case in the model 6 where the inter-household variance was equal to 0.453 and the inter-neighborhood variance to 0.026. Childhood fever was more influenced by variables of individual and household level than by variables of neighborhood level.

In the empty multilevel model, the intra-household correlation showed that 13 % of the variance of the dependent variable - childhood fever - was related to household factors. In contrast, the intra-neighborhood correlation showed that 1.59 % of the total variance was related to neighborhood factors. These two intraclass correlations were relatively low, indicating that the lowest level of analysis, the individual level, explained most of the variance.

The between neighborhood variance was also interesting: although relatively low, this variance was reduced by 50% between the model 1 and the model 6, highlighting the importance of environmental variables to explain childhood fever and proving the relevance of using a hierarchical model to treat these neighborhood data.

Discussion

Our results suggest that childhood fever occurrence is influenced by factors from all three hierarchical levels. At the household level: solid waste and wastewater management facilities play a significant role in the risk of fevers for children. At the neighborhood level, it is the seasonality of a canal and the presence of permanent wetlands which constitute the key risk factors. However environmental factors at the household and neighborhood levels play a relatively lower role than the individual level. This is not surprising, since the first source of heterogeneity in health is individual (Wagstaff et al., 2001). In addition, the number of neighborhoods included in this study is close to the minimum desirable for such models. A larger study may render these results even weightier than in this present survey.

The majority of environmental risk factors included at the household level are associated with recent fever, some in a way we may not expect at a first glance. This is the case for the wastewater management: children, who live in a house not connected to a sewage system, were less at risk of fever than children who live in a house connected to a sewage system. One explanation could be found in the quality of the sewage system. Actually, in many areas in Dakar, the sewage system in general is so deficient, that it poses less risk to simply throw away waste water on the sand where it dries rapidly than to use the sewage system, which will overflow after each rain-shower.

The effect of protective measures might also be seen as unexpected. This result could be a new proof of the limitations of self-reported information: the declaration if using protective measures is not necessarily synonym to use them correctly, which required some questionnaire on habits and day-to-day usage. However, another explanation is plausible: when the nuisance of mosquitoes is high, people use more effective protective measures. In a recent review, Pulford and colleagues (2011) show that a low perceived mosquito density was the most widely identified reason for not using a mosquito net. In the present database, the use of effective protective measures is closely linked to the potential presence of mosquitoes: in neighborhoods where there is a permanent wetland, 67 % of the household declared using at least mosquito nets as protective measures, whereas in those where there is a seasonal wetland, only 55 % of the household declare using at least mosquito nets as protective measures. This proportion is equal to 42% in neighborhood where there is no wetland. In neighborhoods where there is a greater potential of a high density of mosquitoes, the presence of a wetland, the use of protective measures is high. This suggests that the variable used here is a proxy variable for the mosquito nuisance, rather than for an effective protection against mosquito’s bites.

In addition, the issue of the seasonality and the impact that changes of the environmental context have on fever in children is highlighted in this study. In particular, the seasonality of the canal seems to be more strongly associated with the risk of childhood fever than the permanent presence. The presence of a canal in the neighborhood can influence mosquito-borne diseases in two ways. The most obvious case is that of permanent canals, which constitute water bodies, thus favoring mosquito breeding. However, there is also another aspect. In Dakar, the role of canals is to evacuate the excess water that accumulates during the rainy season. Therefore, except for the two-three months of abundant rainfall, these canals are dry. Given the absence of public garbage containers, often these canals serve as waste disposal areas. Hence, when the rainy season arrives, they often overflow, due to the presence of garbage. In this sense, it could be argued that the presence of canals constitutes not only a measure of water bodies in the neighborhood, but also a measure of insalubrity at neighborhood level. In the community dataset, the 12 neighborhoods surveyed that have a canal are in Dakar-city or in Rufisque, at the edge of the metropolitan area.

Conclusion

The purpose of this study was double: to identify environmental threats associated with child fever occurrence and to calculate the variation of fever occurrence attributable to household-level and neighborhood-level contexts. The present analysis addresses fever as a public health issue, without considering the aetiological diagnosis. Recent fever is greatly variable between household and neighborhood. Environmental variables had significant effects. But more information is necessary to interpret all these results deeply. This study is a first step. In particular and as suggested by Merlo and colleagues (2009), an analysis of the variance, and specifically the variance-altering causality, and their mechanisms, would be useful in order to deeply investigate the variation of the causes. Finally, the authors recommend the combining use of multilevel modeling and spatial data (land cover maps and spatial entomological data), mainly to identify more accurately ecological targets for public health policy (Diez-Roux 2008; Chaix et al., 2005).

References

Adongo PB, Kirkwood B, Kendall C. 2005. How local community knowledge about malaria affects insecticide treated net use in northern Ghana. *Trop Med Int Health*, 10:366-372.

ANSD – Agence Nationale de la Statistique et de la Démographie, 2010, Situation économique et sociale du Sénégal en 2009, Dakar, ANSD-Ministère de l'économie et des finances, 263 pages + annexes.

Byrne, N., 2007. Urban malaria risk in sub-Saharan Africa: Where is the evidence? *Travel medicine and infectious disease*, 5(2), p.135–137.

Chaix B, Merlo J, Subramanian SV, Lynch J, Chauvin P. 2005. Comparison of a spatial perspective with the multilevel analytic approach in neighborhood studies: the case of mental and behavioral disorders due to psychoactive substance use in Malmo, Sweden, 2001. *Am J Epidemiol*, 162, p. 171–182.

Chavasse, D.C., Lines, J.D. & Ichimori, K., 1996. The relationship between mosquito density and mosquito coil sales in Dar es Salaam. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 90(5), p.493.

Diallo, A., Ndam, N. T., Moussiliou, A., Dos Santos, S., Ndonky, A., Borderon, M., Oliveau, S., Lalou, R., Le Hesran, J-Y. 2012. Asymptomatic Carriage of Plasmodium in Urban Dakar: The Risk of Malaria Should Not Be Underestimated, *PLoS ONE*, 7(2), p. e31100.

Diez-Roux A. V. 2008. Next steps in understanding the multilevel determinants of health. *J Epidemiol Community Health*, 62, p. 957-959.

Diez-Roux A.V. 2001. Investigating neighborhood and area effects on health. *Am J Public Health*, 91, p. 1783–1789.

Elston, D.M., 2005. Prevention of arthropod-related disease. *Journal of the American Academy of Dermatology*, 51(6), p.947-54.

Filmer, D., and LH Pritchett. 2001. Estimating Wealth Effect without Expenditure Data or Tears: An Application to Educational Enrollments in States of India. *Demography* 38, p. 115-32.

Ghebreyesus, T.A. et al., 2000. Household risk factors for malaria among children in the Ethiopian highlands. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 94(1), p.17–21.

Gubler, D.J., 2004. The changing epidemiology of yellow fever and dengue, 1900 to 2003: full circle? *Comparative immunology, microbiology and infectious diseases*, 27(5), p.319–330.

Holmes J. H., Lehman A., Hade E., Ferketich A. K., Gehlert S., Rauscher G. H., Abrams J., Bird C. E. 2008. Challenges for Multilevel Health Disparities Research in a Transdisciplinary Environment. *American Journal of Preventive Medicine*, 35(2S), p. S182–S192.

Keiser, J., Singer, B.H. & Utzinger, J., 2005. Reducing the burden of malaria in different eco-epidemiological settings with environmental management: a systematic review. *The Lancet Infectious Diseases*, 5(11), p.695–708.

Machault, V. et al., 2009. Highly focused anopheline breeding sites and malaria transmission in Dakar. *Malaria Journal*, 8(1), p.138.

Matthys, B. et al., 2006. Urban farming and malaria risk factors in a medium-sized town in Cote d'Ivoire. *The American journal of tropical medicine and hygiene*, 75(6), p.1223.

Mbow, C., Diop, A., Diaw, A. T., Niang, C. I. 2008. Urban sprawl development and flooding at Yeumbeul suburb (Dakar-Senegal). *African Journal of Environmental Science and Technology*, 2(4), p. 75-88.

Merlo J. 2003. Multilevel analytical approaches in social epidemiology: measures of health variation compared with traditional measures of association. *J Epidemiol Community Health*, 57, p. 550-552.

Merlo, J, H Ohlsson, K F Lynch, B Chaix, S V Subramanian, 2009. Individual and collective bodies: using measures of variance and association in contextual epidemiology. *J Epidemiol Community Health*, 63, p. 1043-1048.

Mendez, F., Carrasquilla, G. & Muñoz, A., 2000. Risk factors associated with malaria infection in an urban setting. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 94(4), p. 367-371.

Mosley, W. H. et Chen, L. C. 1984. An Analytical Framework for the Study of Child Survival in Developing Countries, *Population and Development Review*, 10, p. 25-45.

Ng'ang'a, P., Jayasinghe, G., Kimani, V., Shililu, J., Kabutha, C., Kabuage, L., Githure, G., Mutero, C. 2008. Bed net use and associated factors in a rice farming community in Central Kenya. *Malaria Journal*, 8:64 doi:10.1186/1475-2875-8-64

Pages, F. et al., 2008. Malaria transmission in Dakar: A two-year survey. *Malaria Journal*, 7(1), p.178.

Parizot I., Péchoux S., Bazin F., Chauvin P. 2004. Santé et recours aux soins dans les quartiers de la Politique de la ville du 20ème arrondissement de Paris. . Rapport pour la Mission Ville de la Préfecture de Paris: INSERM, 203 pages. Available at: http://www.u707.jussieu.fr/sirs/Region/RapportSIRS20eme.pdf [Accessed October 19, 2011].

Peterson, I. et al., 2009. Individual and household level factors associated with malaria incidence in a highland region of Ethiopia: a multilevel analysis. *The American journal of tropical medicine and hygiene*, 80(1), p.103.

Pulford, J., Hetzel, M. W., Bryant, M., Siba, P. M., Mueller, I. 2011. Reported reasons for not using a mosquito net when one is available: a review of the published literature. *Malaria Journal*, 10:83 doi:10.1186/ 1475-2875-10-83

Robert, V. et al., 2003. Malaria transmission in urban sub-Saharan Africa. *The American Journal of Tropical Medicine and Hygiene*, 68(2), p.169-176.

Snow, R.W. et al., 1988. Permethrin-treated bed nets (mosquito nets) prevent malaria in Gambian children. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 82(6), p.838–842.

Snijders, T. A., Bosker, R. J. 1999. Multilevel analysis: An introduction to basic and advanced multilevel modeling, SAGE Publications, London.

Staedke, S.G. et al., 2003. Short report: proximity to mosquito breeding sites as a risk factor for clinical malaria episodes in an urban cohort of Ugandan children. *The American Journal of Tropical Medicine and Hygiene*, 69(3), p.244-246.

Subramanian S. V. 2004. The relevance of multilevel statistical methods for identifying causal neighborhood effects. *Soc Sci Med* , 58, p.1961-1967.

Sutherst, R.W., 2004. Global change and human vulnerability to vector-borne diseases. *Clinical Microbiology Reviews*, 17(1), p.136.

Thomson, M.C. et al., 1994. Malaria prevalence is inversely related to vector density in The Gambia, West Africa. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 88(6), p.638-643.

Tolle, M.A., 2009. Mosquito-borne diseases. *Current Problems in Pediatric and Adolescent Health Care*, 39(4), p.97–140.

Tsuzuki, A. et al., 2009. High potential risk of dengue transmission during the hot-dry season in Nha Trang City, Vietnam. *Acta tropica*, 111(3), p.325–329.

UNDP. (2011). Human Development Report 2011. Sustainability and Equity: a Better Future for all. New York: United Nations Development Program.

Van Benthem, B.H.B. et al., 2005. Spatial patterns of and risk factors for seropositivity for dengue infection. *The American journal of tropical medicine and hygiene*, 72(2), p.201.

Wagstaff, A. and N. Watanabe, 2003. What Difference Does the Choice of SES Make in Health Inequality Measurement. *Health Economics* 12, p. 885-890.

WHO – World Health Organization, 2004. The World Health Report 2004 — Changing history. Geneva: World Health Organization.

Yamamoto, S. et al., 2010. Household risk factors for clinical malaria in a semi-urban area of Burkina Faso: a case-control study. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 104(1), p.61–65.

Yohannes, K. et al., 2000. Malaria control in central Malaita, Solomon Islands: 1. The use of insecticide-impregnated bed nets. *Acta tropica*, 75(2), p.173–183.