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Dengue threat: adaptation needs in a disadvantaged neighborhood in Medellín-Colombia

Dengue como amenaza: la necesidad de adaptarse de un barrio desfavorecido en Medellín-Colombia

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ABSTRACT

Background/Objective: Dengue fever is mosquito-borne viral disease with severe forms that are fatal. It is a complex and multi-factorial disease whose control is challenging. This growing public health problem is part of climate-sensitive diseases (seasonality) which call for adaptation strategies, especially among the most disadvantaged and vulnerable populations. The objective of this article is to address the use of insecticide-treated materials as a technological response needed for a human adaptive strategy to dengue risk transmission.

Methods: First-hand data were collected throughout fieldwork performed following a multidisciplinary methodology. A climatic characterization of the study site – Vallejuelos-Medellín-- was performed in order to observe the behavior of two variables: temperature and precipitation. In addition, a socio-entomological survey was carried out in a random sample of 401 households. Based on their socioeconomic characteristics, households were classified into poor and very poor strata.

Results: Storing water is a widespread practice among community residents. Indices of infestation by *Aedes aegypti* mosquitoes recorded at the household level were high in both climatic seasons, but higher during the wet one. All houses surveyed did not have barriers such as window and door screens likely to promote vector control in the indoor environment.

Conclusions: There is a high epidemiological risk all year long, along with an exposure to vector-human contact at the household level. The need for resorting to improved insecticide-treated materials is real. Such an appropriate technological response to a challenging health threat appears to be a valuable adaptation option among the socially disadvantaged.

Key words: Dengue, Epidemiology; Vulnerability; Adaptation, Environment, Medellín-Colombia. (source: MeHs, NLM)

RESUMEN

Antecedentes/Objetivo: El dengue es una enfermedad viral transmitida por mosquitos con formas graves que son mortales. Compleja y multifactorial, cuyo control es difícil. Este problema creciente de salud pública forma parte de enfermedades sensibles al clima (estacionalidad), que exige estrategias de adaptación, especialmente entre las poblaciones más desfavorecidas y vulnerables. El objetivo de este artículo es abordar el uso de materiales tratados con insecticida como una respuesta tecnológica de una estrategia de adaptación humana al dengue, la transmisión de riesgos.

Métodos: La fuente primaria de datos recolectados fue a través del trabajo de campo realizado con una metodología multidisciplinaria. Se realizo una caracterización climática del área de estudio (Vallejuelos-Medellín) que se llevó a cabo con el fin de observar el comportamiento de dos variables: temperatura y precipitación. Además, de una encuesta socio-entomológica en una muestra aleatoria de 401 hogares. En base a sus características socioeconómicas, los hogares fueron clasificados en los estratos pobres y muy pobres.

Resultados: El almacenamiento de agua es una práctica extendida entre los residentes de la comunidad. Se registraron índices altos de infestación por el mosquito *Aedes aegypti* en los hogares mayormente en la estación húmeda. Las casas encuestadas no tienen barreras, tales como ventanas y puertas, lo que las hace susceptibles de promover el control de vectores en el ambiente interior.Conclusiones: Existe un alto riesgo epidemiológico, durante todo el año, junto con una exposición al vector-humano en el ámbito del hogar. La necesidad de recurrir a la mejora de materiales tratados con insecticidas es real. Como una respuesta tecnológica adecuada a una amenaza para la salud, un reto que parece ser una opción valiosa de adaptación entre las personas socialmente desfavorecidas

Palabras clave: Dengue, Epidemiología, Vulnerabilidad, Adaptación, Medio Ambiente, Medellin-Colombia. (fuente: DeCS, BIREME)

Water is indispensable to life and, like food, is part of the first layer (physiological needs) of the hierarchy of needs as described in one of the personalities' theories (1). Fulfilling the deficit needs, inherently basic, is not only crucial for life, but also an acknowledged human right.

However, there still exist discrepancies in the availability of and access to clean water in many parts of the developing world. Such differentials in a context of rapid urbanization lead to secure water at the household level, in ways that pose threats to the environment and are challenging in terms of public health.

Access to clean running water available 24 hours all year long, good sanitation and regular garbage collection that discourage the proliferation of rodents and insects, cannot be taken for granted in many underserved urban communities of Latin America. Vallejuelos in Medellín (Colombia), a slum home to people who have been displaced to escape community-wide disruptions (e.g. armed conflicts), and/or who have invaded unplanned settlements is not an exception. It is a context where water storage related-practices interact with the ecology of the *Aedes aegypti* mosquito, main vector of dengue fever in the Americas.

Dengue, an infectious disease said to be the most important arboviral one, afflicts humans in many countries worldwide and can lead to death throughout its severe forms: dengue shock syndrome (DSS) and dengue hemorrhagic fever (DHF). The disease is hyper endemic, a term which refers to the circulation of all four distinct virus serotypes (DENV-1, DENV-2, DENV-3 and DENV-4), and is characterized by a heavy burden felt at differing levels (2,3,4). However, whilst the disease is expanding, a licensed vaccine is still pending.

In the Americas, an important share of the health sector budget is diverted to this single disease. As illustrated by regional health authorities, dengue-related expenditures increased over 100% in 23 countries for the period 1996-7, and disease incidence also increased during the same period of time (5). Traditional vector control measures, mostly consisting of applying larvicides and adulticides (e.g. temephos; space spraying and fogging), have been criticized for being vertical and ineffective since re-infestation occurred (6,7).

Research on dengue has on the one hand established the influences of abiotic environmental factors such as humidity and temperature acting in tandem or sequentially (8,9,10). On the other hand, it has been found that dengue vectors live close to humans, need their blood, are produced in water-holding containers kept in their residences, and rest in the shade of their yards (11,12).

Sharing a space with humans and feeding preferentially on them imply exposure to bites. Infective bites represent a threat to human health and life, and vulnerability can make a difference. An effort at apprehending vulnerability wholesomely, is relevant to take into account the embeddedness of humans' coping capacity, adaptive capacity and resilience. It is reflected in the following definition: "Vulnerability means not lack or want, but exposure and defencelessness. It has two sides: the external side of exposure to shocks, stress and risk; and the internal side of defencelessness, meaning a lack of means to cope without damaging loss." Chambers (1995: vii) (13).

It is acknowledged that climate change and its impacts are surrounded by a range of uncertainties. The capacity of human formations to adapt to uncertainty in a fast-pace changing world is therefore important. Under a climate change scenario with two degrees warmer and the possible implications for the spread of a viral disease like dengue fever (14, 15), whether to changing or not human practices regarding water storage and emphasizing individual protective measures against vector-human contact, may have important repercussions for human health.

The potential and actual capacity of water-holding containers to generate mosquitoes breeding, raise legitimate concerns about what and how appropriate responses should be framed to mitigate the consequences of reaching vector densities above the transmission threshold. Thresholds are conceived as a key measure to the Ae. aegypti dengue system (16).

This article seeks to address the use of insecticide-treated materials (ITMs) as a technological response needed for a human adaptive strategy to the growing dengue threat. It aims to focus on the socially disadvantaged with a view to documenting an aspect of their vulnerability to dengue risk transmission.

METHODS

The methodological approach to this study was multidisciplinary. It brought together methods from the natural, bio-medical/health and social sciences. It was implemented in order to generate first-hand data from 2006-7 in Vallejuelos. This setting is a poor-resource neighborhood of Medellín in Colombia.

A climatic characterization of the study site was undertaken. In doing so, field observations are performed in order to look at the presence of significant relationships between atmospheric conditions and the behavior of Ae. aegypti mosquitoes during a

period of time.

The climatic characterization of the study site was based on temperature and precipitation data, more specifically mean temperature and cumulated precipitations. Data on these variables were obtained from the nearest local meteorological station Olaya Herrera.

Data reliability was ensured through building a monthly series. Accordingly, the anomalous values for the corresponding longitude and latitude as presented in the National Oceanic Atmospheric Administration (NOAA) revised analysis were taken into account.

A community fieldwork was conducted in Vallejuelos. Data collection took place during the wet season from October to December 2006 and the dry season in January 2007. Socio-entomological surveys were conducted in two social strata classified as poor and very poor (or poorer). The classification was based on their socioeconomic characteristics such as annual income, educational achievement, housing construction material. In addition, visual data were collected.

Sampling was probabilistic and estimated in accordance with the guidelines for entomological sampling approved and detailed by the World Health Organization (17). A simple randomized sample of 401 households was used. The measurement error was 5%.

Besides documenting some social and behavioural aspects, entomological information was sought about the number of potential breeding sites and positive breeding sites, the presence of adults mosquitoes in various areas of the house (e.g. bathrooms, bedrooms, yards) in order to determine entomological indices.

These entomological indices are defined as follows: the Container index (CI) is the number of containers with immature stages per 100 containers with water; the Breteau index (BI) is the number of containers with immature stages per 100 houses; the House index (HI) is the number of houses having immature stages per 100 houses; the Pupal index (PI) is the number of pupae per person in a given area.

Materials collected with pipettes and pans were taken to the medical entomology lab at the Universidad de Antioquia (Medellín-Colombia). In order to carry out the quantitative analysis of data gathered within community fieldwork, the statistical package SPSS was used. Statistical analysis of the socio-entomological surveys is only descriptive. Therefore, no comparison tests or regression were performed.

The procedure for gathering data was not intrusive and adhered to the ethical guidelines of research involving animal and human subjects. An oral informed consent was sought prior to collecting data, and the work to be performed was explained in simple terms. The lives of research participants and their privacy were not under threat. Consequently, ethical clearance by a specialized board was not considered necessary after reviewing the research proposal and prior to funding approval.

The general context: An overview

Medellín, capital of the department of Antioquia, is one of the largest cities of Colombia with an extension of 63, 612 km2 and a population of about 6 million. Colombia is a dengue-endemic country where all four dengue virus serotypes have been identified. DENV-3 is the one found countrywide and with a higher epidemiological impact (18). A phylogenetic study of DENV-3 conducted in the Metropolitan area of Medellín found that two distinct variants of DENV-3 subtype III co-circulated during at least five years (19).

At the national level, the co-circulation of different genotypes was confirmed. Genotype III of DENV-3 is not only widely distributed, but also coupled with genotype I (Southeast Asia/South Pacific genotype). Such simultaneous circulation has been associated with the severity of infection with DENV-3. Over the last decade, there has been an increase in dengue incidence in South America, and it is in Colombia that most cases of DHF and related fatalities have been recorded (20).

No vaccine against dengue is available for the time being. Therefore, the focus is on the vector. Approaches to vector control and disease prevention may encompass multiple interventions with intersectoral collaborations or be limited to single interventions. A dengue epidemic prevention program with a multi-faceted social mobilization program was implemented in Bucaramanga, in the department of Santander. Santander is located northeast. High incidences of dengue fever and DHF cases were recorded in the 1990's.

Information, education and communication (IEC) strategies involving popular theatre and songs, the application of a behavioral change model with five stages mainly directed at housewives, and increased community motivation to participate in a special day (Thursday) dedicated al dengue were combined. They resulted in decreasing entomological indices (e.g. House index) over a five-year period (21).

A common trend in outbreak management consists of environmental management with larval habitat reduction (e.g. application of larvicides, removal of discarded tyres). Besides selected indoor spraying, adults are targeted in high risk areas through fogging

or focal outdoor spraying with the use of truck-mounted guns/spray guns or aircraft when spraying is aerial.
In 2010, more than 174 millions in Colombian local currency have been invested in purchasing 5.040 litres of Malathion, an insecticide used to fumigate dengue vectors (22).
An authority, the Colombian's National Institute of Health (NIH) which among other responsibilities officially reports cases of infection in the country, has concerns over the spread of the Ae. aegypti mosquitoes at higher altitudes and a combination with rising temperature (23).
Another concern from the Ministry of social protection over rural border areas led to seek bilateral agreements with neighboring countries, especially Ecuador. Carrying out activities of education, prevention, diagnostics and treatment in conjunction, is expected to contain the spread of dengue fever (24).
Within borders, demographic and urban dynamics also contribute to the circulation of the serotypes and spread of the disease nationwide. An important phenomenon in Colombia, though reported to be in decrease, is the enforced displacement of civilian peoples or PSD in Spanish acronym (personas en situación de desplazamiento).
Antioquia is one of the departments receiving the highest number of PSD. There are about 1.8 million people displaced by violence in Colombia, the majority of whom are AfroColombians, particularly afflicted by the highest indices of poverty (an annual income of $500 US versus $1 700 US for non-Black Colombians) and illiteracy (32 % versus15 % among non-Blacks Colombians and only 2 % at a university level). They are disadvantaged in social issues, health care, nutrition, government, military and diplomatic services (25).
Human development in the departments of Chocó, Chauca and Nariño, respectively populated by people from African descent and natives, is in sharp contrast with the Capital District of Bogotá. The human development index (HDI) which provides "a broadened prism for viewing human progress and the complex relationship between income and well-being", has steadily improved from 1980-2007 (26).
According to the same source, Colombia ranked 77th out of 182 countries with an index of 0. 807. However, it does not reveal much about a persistent social exclusion and the realities that a growing population of underserved urban poor are faced with. The country is rapidly urbanizing with 72% of the population living in administrative centres. It has been stated that 780 out of the 836 municipalities in Colombia have conditions adequate for mosquitoes to breed (27).

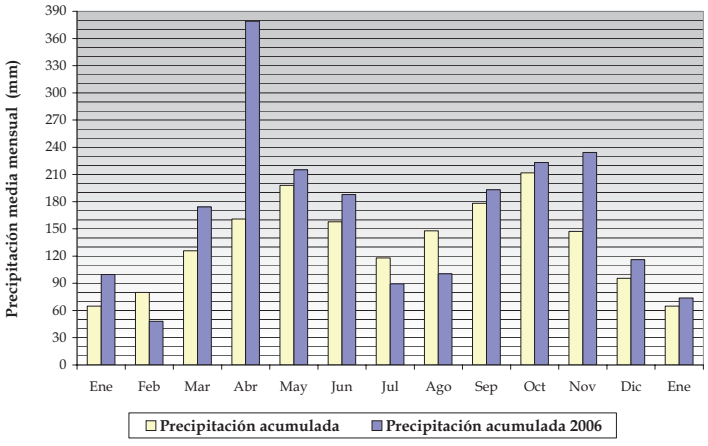
As recently reported in the media, epidemics provide the opportunity for highlighting the vulnerability to the disease at an official level:

> *"Health officials said Colombia's dengue outbreak has revealed vulnerabilities in the country's health and environment systems. About two thirds of Colombia's cities report conditions that contribute to dengue epidemics, such as poor sanitation, improper garbage and tire disposal, inadequate rain water drainage, and risky water storage practices." (28).*

RESULTS

It could be learned from the climatic characterization of the study area that it has a highland tropical climate with an altitude near to equatorial latitudes. Average temperatures vary between 21 ºC and 22 ºC. The configuration of the northern Cordillera allows an efficient impact of humid winds to generate abundant precipitations in localities of the Cordillera. Values in precipitations recorded from September to January (2006-7) indicate an anomalous wet period prior to the dry season (Figure 1)

Figure1. Cumulated precipitation. Olaya Herrera-Medellín



Since June 2006, it has been observed that temperature during that year is above the climatic mean at about 0.6 ºC till November. That difference increased in December and January until reaching an abnormality of 1.3 ºC. Therefore, during the last half of the year, temperatures above normal persisted.

Community fieldwork data

Community fieldwork conducted in Vallejuelos revealed the presence of dengue vectors in the private sphere,

located in a variety of water-holding containers. These containers are commonly used for water storage, to carry water, and to perform domestic chores.

198 out of the 401 households consisted of poor and 203 of very poor, respectively representing 47% and 53% of the sample. Positive containers were found in both social strata. However, the highest indices of infestation were recorded among the poor (87.2% vs.12.8%). As a matter of fact, the pupal index (PI) is 0.464 for the poor vs. 0.086 among the poorest. This index was higher than the adult one (AI) for the wet season. A feature of the study site is that the traditional stegomyia are generally above 5%.

With few exceptions, most water-holding containers were not covered. These are for example the canisters, pots, and buckets. In very few occasions, it could be observed an improvisation to have the buckets covered. A round piece of wood was used for that purpose.

For having a small closing cap, gallon drums popularly referred to as bongos represented the exception. What is noteworthy about gallon drums was their productivity. They resulted less frequently positive than the other containers. In contrast, the low concrete tanks or *posetas* in the local terminology were the most productive containers (67.5% among the poor).

Also important in terms of their productivity were the containers located in backyards. They may be of seldom use or simply discarded. They were labelled in a category "others" and often consist of wasted pots and bottles.

Housing in both social conditions

Housing in Vallejuellos, a low-income locality, varies according to the mode of acquisition. Many of the residents are either invaders or displaced from their communities of origin. The displaced proceed from insecure areas in the country owing to internal armed conflicts. Some of the residents (78.7% of the poor) are beneficiaries of social housing programs. Unemployment is considered an important problem in the community.

Lack of window and door screens: A common feature

Regardless of the social condition and being beneficiary or not of a housing program, an overwhelming fact is that all the houses are not equipped with physical barriers such as window and door screens (Figure 2).

Figure 2. Using screens or not

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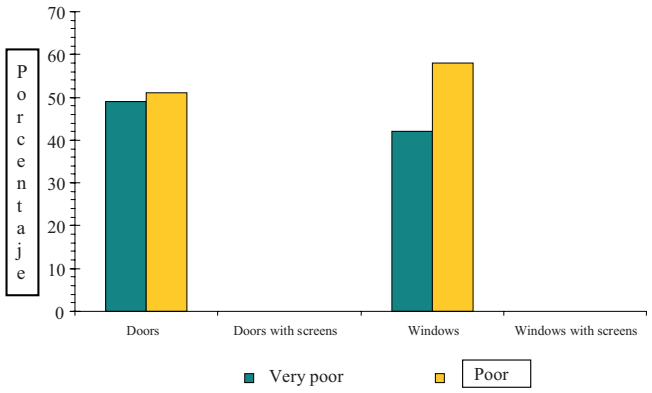

This common trend also raises an issue of need in terms of health protection. During the day, windows are left open in order to have the house ventilated. It also permits to take advantage of daylight. Ae. aegypti are mainly daytime feeding mosquitoes.

DISCUSSION

Findings of this study on a water-associated vector-borne disease provided a description of climatic conditions, human practices at residential levels, and vector abundance in a environment where the coexistence of proximal and distal factors cannot be overlooked. It must be underlined that entomological indices recorded during the wet and dry seasons were high in a setting with a highland tropical climate.

A warranted access to clean water on a daily basis appears more to be a luxury than a norm, or a right among the underserved in many parts of the developing world. Consequently, people need to secure water for their daily consumption and put up with situations of shortage. As usually noted about seasonality and vector abundance, water scarcity encourages water storage for a longer period of time, especially during drier months and times of infrequent supply on the one hand.

On the other hand, excess rainfall provides open stagnant water and opportunities for harvesting and storing water, especially among the socially disadvantaged. Rainwater is important in the socioeconomic lives of the "have not". They often use it for their domestic chores and thus, can save water from the pipes. For the purpose of social reproduction, breeding grounds are provided to dengue vectors.

Both findings in the study site and from the current state of knowledge on dengue highlight the threat

of being afflicted by the disease. More pupa than adults were found in water-holding containers at the household level. The pupae stage is very short (two days) and adults have a feeding preference on humans, with smaller adults female feeding more often to provide proteins to their eggs. In addition, the complete cycle of dengue transmission does not exceed two weeks (29).

Vectors' adaptive capacity is not to be underestimated. As noted about the opportunism of weeds, rodents, insects and micro-organisms, they have the ability to rapidly reproduce. Moreover, they count with features such as having huge broods, small body sizes, wide-ranging appetites and being good at dispersal and colonizing new environments (30).

Humans are at disadvantage with the shrinking availability of mosquitoes' natural predators due to agricultural practices. Findings of a research study in agronomy equated the map of the invasion of Aedes mosquitoes and the United Republic of soy encompassing neighboring countries of South America (Argentina, Bolivia, Brazil, Paraguay and Uruguay) where yellow fever and dengue are now taking their toll.

Considerable deforestation for the cultivation of soy beans and the massive use of herbicides (e.g. glisofato or Round up, Atrazina, 2-4-D, Diquat) disturb the equilibrium of the ecosystem. Such practices also lead to the destruction of the natural habitat of fishes, amphibians, toads, frogs, and decimate their population (31). Hence, in the absence of these natural predators, mosquitoes can survive and be active over a longer period of time.

A vaccine against yellow fever already exists, but it is not yet the case for dengue. This disease is now re-emerging in Argentina. Therefore, the ability of individuals and institutions to cope with change in order to adapt to the uncertainty of a changing environment (32) remains key to preserving human health.

In contexts of hyper endemicity of dengue viruses and low herd immunity, and where health services are ill-equipped to provide proper care in a timely manner, losing control over opportunists Ae. aegypti is likely to end up in damaging dengue outbreaks. Experts have made it abundantly clear that the odds of developing DHF increase with a previous infection with a distinct serotype, since lifelong immunity is limited to a single serotype (33).

At a macro level, early warning systems are recurrently recommended and/or endorsed as a response against the potential climate change-related health impacts. The 1990s have witnessed the development of disease early warning systems referred to as DEWS (34). Drawing on data from Thailand, the National Aeronautics and Space Administration (NASA) succeeded at developing a dengue early warning system (35). However, the success story of the NASA is not yet widespread.

Models used to predict the dengue transmission cycle require accurate information on a range of parameters. Their application implies a consistent monitoring and therefore, in developing countries where the health systems are hampered by many constraints, dengue early warning systems have been considered less suitable. Making the models more affordable and monitoring less time consuming, are the recommendations made by experts (36).

At an individual level, a simple technological response consists of using ITMs such as window and door curtains, jar covers and bed nets. These tools have been improved over time with a long-lasting effect and proven effective in trials in the Americas and in Asia (37,38).

By impregnating them with safe insecticides (e.g. permethryn), users get involved in controlling adult vectors in the indoor environment, and to some extent in the process of empowering their communities. An active participation of the beneficiaries in vector control is likely to induce sustainable impacts on their lives and enhance the epidemiological relevance of an indoor environment focus.

In a country like Cuba where vector control measures rely heavily on spraying and/or fogging, resorting to the use of bed nets at home in times of epidemics, appeared to be a valuable option to reduce disease transmission in households with an infected patient (39). In another context in southern India, the use of nets has proven effective to control disease transmission in a hospital environment during dengue fever outbreaks (40).

Although questioned, traditional vector control measures are still predominant. However, Ae. aegypti mosquitoes are successful at adapting to urban environments to the point of surviving in sceptic tanks (41). Under conditions suitable to their survival, an imbalance in resilience and adaptation detrimental to humans may occur. Therefore, putting to good use innovative technologies is important to improve vector control efficiency and at the same time, would be conducive to reducing the knowing-doing gap.

In a recent report on a climate-related project, experts

in the Assessment of Impacts and Adaptation to Climate Change (AIACC) addressed climate change adaptation in terms of deficit, and raised the need for creating the conditions to enable adaptation and integrate it with development (42). In the particular case of dengue, poverty, unplanned urbanization and lifestyle represent some of the threads of the tapestry to take into account when the acknowledged capacity of humans to take precautionary action is addressed.

CONCLUSION

As illustrated in this paper with the case of Vallejuelos in Medellín (Colombia), water storage practices in conjunction with some climatic stimuli provide an ideal environment for the breeding of Ae. aegypti mosquitoes as reflected in the entomological indices recorded. Significant differences in entomological indices were observed during the wet season. Data on the whole revealed a high epidemiological risk all year long, and did not contradict the intimacy of dengue vectors with humans.

Regardless of the type of housing, the lack of protection as a precautionary action to reduce human-vector contact appears more to be the rule than the exception. A permanent high vector density is of concern. Of greater concern, is the lack of individual protective measures as revealed by a notorious absence of physical barriers in homes likely to reduce possible vector-humans' infective contact.

The urban population is projected to grow worldwide, and this implies an increasing population density in urban centers with a growing trend of informal settlements. Crowding, associated with poverty, is beneficial to dengue vectors since it supplies them with ideal sources of blood meals. Domestic water storage practices also make breeding sources available to dengue vectors.

With more inhabitants in cities, more demand for potable water (a vital liquid) is to be expected. If solid waste collection schemes, water supply and sanitation infrastructure are not improved, both exposure and susceptibility to the disease are likely to be increased among slums dwellers. The same may hold true for the persistence of high unemployment and poverty rates among them.

IEC programs, along with clean-up campaigns are so important for the prevention and control of dengue that, related initiatives should rather be integrated than isolated. Although necessary and promising, clean-up campaigns and behavioural change require sustained efforts that may be challenged in the long run. On the other hand, lagging behind the adaptive capacity of dengue vectors would jeopardize human health –especially the health of the socially disadvantaged urbanites.

From such perspective, being equipped with new and improved technologies seems far from being redundant or counterproductive among the underserved. As part of an adaptive strategy, it is likely to address their need as persons in a situation of vulnerability, for being provided with a protective indoor environment. ITMs have been improved and their field-tested effectiveness provides a relevant ground for framing and promoting them as an appropriate response thus far.

This study is not exempt from limitations as it can be the case for ITMs. It does not go beyond a descriptive analysis, and observations should have been made during a longer period of time. However, it has generated interesting primary data from a real-life setting, based on a multidisciplinary approach. Another considerable strength of the study resides in addressing the need for an adaptive option to a mosquito-borne viral disease like dengue which appears urgent, meanwhile attempts to develop vaccines and to provide genomic-oriented responses are underway.

Since dengue represents a growing challenging public health problem, long-term adaptation strategies likely to reduce the burden of the disease, are more needed than coping strategies suited for overcoming a specific crisis. Empowering at-risk populations to access and adopt them, and use them properly is pressing. Future research work should go in this direction given the significant weight of the social determinants of health addressed herein, the projection of a two degree warmer temperature by experts in global warming, and the lack of means to cope with external shocks among the socially disadvantaged.

Framing adaptive strategies for humans is legitimate and necessary to adequately address their vulnerability and resilience as far as the impact of both climate-sensitive and poverty diseases is concerned. However, it should also be kept in mind that meeting the need for an adaptive capacity, calls for an increased partnership between the policy community and the beneficiaries.

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