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Spatial Urban Environmental Change and Malaria/Diarrhoea Mortality in Accra, Ghana

A thesis

By

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Declaration

This thesis is an original product of field research work undertaken in Ghana with data analysis and write-up in Germany under the joint supervision of Prof. Dr. Alexander Kraemer (University of Bielefeld, Bielefeld) and Prof. Dr. Juergen May (Bernhard-Nocht Institute for Tropical Medicine, Hamburg). I declare that the thesis is not under consideration for the award of a degree in any university and all resources and previous works consulted are duly cited and acknowledged in the reference section.

Sign ……

Julius Najah Fobil

Sign ……

Prof. Dr. Alexander Kraemer

Sign ……

Prof. Dr. Juergen May

Dedication

My late parents and my late brothers (Waanon and Udin).

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First of all, I thank the Almighty God for the internal energy and motivation for this work! There were several individuals who were connected to the success of this work and having to acknowledge all will mean a second thesis and I will only mention a few here.

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List of Acronyms

MA	Millennium Ecosystem Assessment
GDP	Gross Domestic Product
CO	Carbon monoxide
HCs	Hydrocarbons
Ghana-EPA	Ghana Environmental Protection Agency
GHS	Ghana Health Service
TOR	Tema Oil Refinery
FTDA	Fuel Tanker Drivers Association
WHO	World Health Organization
BE	Built Environment
BP	Blood Pressure
GAMA	Greater Accra Metropolitan Area
MoH	Ministry of Health
CHIM	Centre for Health Information Management
GSS	Ghana Statistical Service
GIS	Geographic Information System
ICD	International Classification of Disease
NOS	Not Otherwise Specified
TKN	Total Kjeldahl Nitrogen
COD	Chemical Oxygen Demand
TOC	Total Organic Carbon
EAs	Enumeration Areas
PMR	Proportional Mortality Ratio
WC	Water Closet
KVIP	Kumasi Ventilated Improved Pit latrine
SES	Socioeconomic Status
PCA	Principal Component Analysis
GPS	Geographic Positioning System
GDHS	Ghana Demographic and Health Survey
VRS	Vital Registration System
IDR	Instantaneous Death Rate
OPD	Outpatient Department
ORS	Oral Rehydration Salt
MDGs	Millennium Development Goals

Abstract

Introduction and Theoretical Background: Environmental change processes, including demographic and climate change, have been widely predicted to have profound consequences (both direct and indirect) on human health. There is a strong consensus that such health impacts of environmental change would vary in magnitude at multiple scales and across population groups depending on the level of vulnerability and adaptive capacity of the different populations at risk. In terms of scalar variability, the health impacts of environmental change might differ by season and across spatial boundaries. While there is a complete understanding that the magnitude and scale of environmental change process are driven by a combination of both demographic and socioeconomic forces, the fractional contribution of the different forces to the overall health outcomes remains poorly understood. For instance, it is well established that health outcomes are not evenly distributed across different populations and that different individuals in a given population differ in susceptibility to different risk factors. But the question is how much of the difference in susceptibility is contributed by say hygiene factors and sanitation, low salaries, genetic factors, etc? A substantial body of literature exists which seeks to explain a fast growing phenomenon of social and spatial segregation in health. A range of structural, material, and socio-cultural factors have been implicated. The premise of the argument is that access to resources and opportunities such as wealth, education, employment, place of work, professional category, and health care are themselves unevenly distributed, and this inequity underlies the social distribution in health status. However, how much each of the different components explains the observed distribution in health outcomes and the expressed health inequality remains unexplained. More recently, while market-oriented economic and social policies intended to deregulate the labour market and constrain social security have widened inequalities in social position in many areas, the associations between these social and economic events and health outcomes remains poorly understood and weakly articulated.

What is more, urbanization which is driven by demographic pressures ultimately affects the distribution of the expressed urban health outcomes. In the urban areas, the demographic and socioeconomic pressures drive uneven availability of basic services,

differences in urban living arrangements and variation in urban neighbourhood characteristics and which may all influence health outcomes in a variety of ways. In Ghana, urban sanitation infrastructure is generally open-drain type with narrow drainage channels which constitute breeding media for insect vector, vermin and other micro-organisms. Limited municipal budgets are insufficient to provide city-wide public facilities and for this reason, sanitation services are not distributed evenly across the city providing for high heterogeneity in levels of environmental quality – thus certain areas have more intense waste accumulation than others. Areas close to rivers, lagoons, wetlands and other large surface water bodies are more prone to flooding and offer cheaper lands for residential purposes than those areas far away from these water bodies. Therefore the flood prone areas tend to attract low income groups largely because of decreased market-value for those lands. An exploration of existing literature reveals evidence of such associations between morbidity on the one hand and urban environmental quality conditions and socioeconomic inequalities on the other hand. Ample evidence exists in literature which shows that significant human-induced urban environmental modifications are slowly altering the dynamics of disease causation and this has mobilised research efforts into evaluating the association between urban environments and human health outcomes. The potential effects of such environmental modifications to change the quality of urban water supply, urban air quality, provide breeding opportunities for insect vectors and pathogens have generated considerable research interest for several years now. Potential changes in the incidence and distribution of malaria and diarrhoea are two most frequently mentioned morbidity outcomes related to such urban changes. Urban areas with higher waste accumulation are more generally able to offer better breeding opportunities for insect vector proliferation and disease transmission compared to areas where waste lifting is far more frequent. In a nutshell, the result of the combination of differing levels of sanitation services, waste collection, different housing arrangements and the influence of surface water bodies produce urban complexes with high heterogeneity in malaria and diarrhoea transmission rates. Despite the high heterogeneity and spatially varied urban environmental conditions, questions remain whether the same level of heterogeneity is exhibited in the distribution of the observed malaria and diarrhoea mortalities within the urban complex. For instance,

there is a knowledge gap regarding how the different environmental conditions, urban neighbourhood characteristics (e.g. hygiene –"toilet & bath facilities", "water supply & sanitation" –sewerage, rate of solid/liquid wastes collection, sources of water for domestic use, housing and living arrangements (i.e. types of construction materials, number of people per housing unit and type of structure) singly or in combination, interact to influence the overall distribution of the observed urban malaria and diarrhoea mortalities. Whereas there is a clear understanding of the association between the state of wastes disposal, pathogen load in storm water and outbreak of enteric diseases such as diarrhoea and cholera in many urban settings surrounded by garbage fields, there is no evidence showing whether or not the same kind of association exists between the urban environmental conditions and the observed diarrhoea mortality in the urban complexes. Moreover, very little is understood about how much each of the urban conditions contributes to the observed urban malaria mortalities in rapidly urbanizing areas in low income economies.

Study Objective: The main objectives of this study therefore were to examine the observed urban malaria/diarrhoea mortalities at several levels (e.g. age-specific, sex-specific and cluster levels) and to assess the association between the observed malaria/diarrhoea mortality and the spatially varied neighbourhood urban environmental and socioeconomic conditions in Accra, the capital city of Ghana and a large urban setting in Africa. The study integrated urban environmental and socioeconomic data from census sources and mortality data from routine sources into GIS which allowed for the various aspects of the analysis to be undertaken. At age-specific and sex-specific levels, the study did not only determine whether there were real differences in age-specific malaria and diarrhoea mortalities, but also sex-specific differences as a consequence of the spatial change in the burden of environmental risk across the city. The study additionally assessed the different levels of association between socioeconomic status and the neighbourhood urban environmental quality conditions, socioeconomics and health (malaria and diarrhoea mortality), neighbourhood urban environmental quality conditions and health as well as the assessment of the overall spatial distribution of risks and excess malaria and diarrhoea mortalities at both cluster and city levels.

Methodology: The author collected and analyzed routinely generated health data (death events) from the Ghana Vital Registration System and environmental and socioeconomic data from the Ghana census 2000 database. In order to achieve the complex objectives of the study, the author adopted a multi-strategy approach to the analysis. First, a summary measure of mortality (the cluster level fraction of deaths due to malaria and diarrhoea) was computed as a measure of health combining both epidemiologic and statistical approaches. Second, the author computed the relevant summary measures (e.g. proportions, per capita rates, etc.) appropriately for both the socioeconomic conditions and the neighbourhood urban environmental quality conditions and employed principal component analysis (PCA) as a data reduction strategy to handle the large number of variables included in the analysis. The investigator then employed generalized linear models (GLMs) for determination of associations, spatial autocorrelation at global scale (Accra-wide level) to detect general clusters or outliers using the Global Moran's I and other geo-statistical approaches (geographically weighted regression – GWR and LISA) to assess the spatial associations between the health summary measure on the one hand and the socioeconomic and environmental conditions on the other hand.

Results: For demographic and health considerations, this study found no evidence of a difference in both malaria and malaria mortalities across sex, despite clear difference in age-specific mortality patterns. The results of bivariate analysis showed wide variation in levels of association between the socioeconomic variables and environmental conditions, with strong evidence of a real difference in environmental quality across socioeconomic classes with respect to total waste generation ($p < 0.001$), waste collection rate ($p < 0.001$), sewer disposal rate ($p < 0.001$), non-sewer disposal ($p < 0.003$), the proportion of households using public toilets ($p = 0.005$). Socioeconomic conditions were therefore observed to constitute important drivers of change in environmental quality, thus leading to a conclusion that interventions aimed at infectious disease prevention and control if they were to be effective could benefit from simultaneous implementation with other social interventions.

In respect of the analysis of socioeconomic conditions and health, the study found that while malaria mortality showed a strong evidence of significant difference across the socioeconomic quintiles ($p < 0.001$), no such evidence of a difference in diarrhoea

mortality was observed across the socioeconomic classes (p = 0.288). Additionally, multivariate analyses showed much weaker evidence of association between area-based socioeconomic status (SES) and diarrhoea mortality than the evidence of association observed between area-based SES measures and malaria mortality. This observation led to the conclusion that health policy reforms in Ghana were perhaps more effective/responsive to urban diarrhoea than urban malaria mortality and that the area-based measures of SES could perhaps be included in the suite of potential risk factors in future case-control studies to determine city-wide risk factors for urban malaria mortality. Finally, the results of the environment and health as well as the spatial analyses showed that whereas there was a strong evidence of a difference in relative mortality of urban malaria across urban environmental zones of differing neighbourhood environmental quality conditions, only limited evidence of mortality differentials for diarrhoea was observed across these zones. Additionally, whereas bivariate analyses showed evidence of varying strengths of association between the environmental variables and malaria mortality, no evidence of association was found between diarrhoea mortality and the environmental variables. Regions of hotspots, cold-spots and excess mortalities were observed to be associated with some socioeconomic and neighbourhood urban environmental conditions, suggesting uneven distribution of risk factors for both urban malaria and diarrhoea in areas of rapid urban transformation. The findings of this component of the study provided evidence for the conclusion that environmental management initiatives intended for infectious disease control could substantially reduce and/or lower the neighbourhood urban environmental-quality-attributable fraction of deaths due to urban malaria more than that due to urban diarrhoea in rapidly urbanizing areas in a low income setting.

Conclusion: The overall conclusion from this analysis was that, while inequalities in health status were linked to multiple pressures, especially in the weak economies, their strong association with the socioeconomic and environmental disparities also meant that health inequalities were amendable and could be addressed through effective social sector reforms and sound environmental management policies. Whilst an array of micro-level and macro-level social forces were driving the widening health divide, addressing the common structural, material, socio-cultural factors, environmental and public services

could perhaps have considerable and rapid benefits which would hopefully close up the health inequality gaps in cities of low income economies. A subsidiary conclusion was that urban health policy reforms would benefit from longitudinal studies designed based on initial vulnerability mapping via screening which sought to establish the range of risk factors operating at both micro- and meso-levels in rapidly urbanizing areas in low income economies.

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