UNIVERSITY OF CAPE COAST

EFFECT OF HOUSEHOLD WATER TREATMENT ON UNDER FIVE DIARRHOEA IN GHANA

IDDRISU SALIFU

2020

UNIVERSITY OF CAPE COAST

EFFECT OF HOUSEHOLD WATER TREATMENT ON UNDER FIVE DIARRHOEA IN GHANA

BY

IDDRISU SALIFU

Thesis submitted to the Department of Economics Studies of the School of Economics, College of Humanities and Legal Studies, University of Cape Coast, in partial fulfillment of the requirements for the award of Master of Philosophy Degree in Economics

MAY 2020

DECLARATION

Candidate's Declaration

I hereby declare that with the exception of references to other people's work which have been duly acknowledged, this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature……….............................Date…………………….

Name: Iddrisu Salifu

Supervisors' Declaration

We hereby declare that the preparation and presentation of this thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature……………………… Date…………..

Name: Dr. Emmanuel Ekow Asmah

Co-Supervisor's Signature…………………………… Date……………..

Name: Dr. James Atta Peprah.

ABSTRACT

Improving access to safe water, is on the frontline of efforts to achieve the anticipated 2030 Sustainable Development Goal 3 and 6. However, unsafe drinking water, remains a critical issue of concern in Ghana, causing high mortality and morbidity rate among children under the age of five years, especially due to diarrhoea disease. Household water treatment (HWT) can effectively reduce the exposure to unsafe drinking water, a major cause of diarrhoea diseases. Assessing the relative effect of household water treatment (HWT) on under five diarrhoea in Ghana, is essential for enhancing the adoption of HWT. This thesis examines the effect of household water treatment (HWT) on child under five diarrhoea in Ghana. The study used a dataset obtained from the Ghana Demographic and Health Surveys (GDHS) conducted in 2014. Probit and endogenous treatment effect models were employed for the analyses. Results show that household water treatment (HWT) and improved sanitation are likely to reduce the prevalence of diarrhoea among children aged under five in Ghana by 30 percent and four percent respectively. Even though previous studies in Ghana on this issue showed that drinking improved water source reduce the odds of under five diarrhoea. This study found that drinking from improved water sources rather increases the odds of diarrhoea by about three percent and the potential explanations for this rather puzzling finding is that improved sources are not monitored once provided. The study recommends that the Health Promotion Unit through Community Nurses (CN) and the Community-Based Health Planning and Services (CHPS) of the Ghana Health Service (GHS), should advocate and intensify education programs on the importance of adopting household water treatment (HWT) and practicing proper sanitation in order to curb child diarrhoea. Also, the Ghana Standards Authority (GSA) should regularly monitor sachet and bottled water and other improved water sources for microbial quality to ensure that consumers are offered clean and safe drinking water in Ghana.

KEY WORDS

Diarrhoea

Ghana

Sanitation

Under-five

Water Treatment

ACKNOWLEDGEMENTS

I would like to express my profound appreciation and gratitude to my supervisors, Dr. Emmanuel Ekow Asmah and Dr. James Atta Peprah for their patience, constructive criticism and guidance throughout the study. Also, my gratitude is expressed to Mr. Kwabena Nkansah Darfor and Gloria Essilfie for their professional advice of my work. A big thank you to Mr. Abdulai Kasim of the Department of Physician Assistantship and Nutrition, University of Cape Coast and Clement Oteng for their support, especially in those difficult moments when academic deadlines collided. A special thank you to my mother Mrs. Ayeshetu Awini Adagang for her guidance given me. She sacrificed all to make me feel comfortable in life and I am never going to forget all that she has done to make me who I am today. Finally, but not least, my lovely wife Fati and son Mohammad Muzammil Ibn Iddris for their patience and encouragement. To Usman Adam for his constant support.

DEDICATION

To my loving wife Fati and the kids

With love and affection

TABLE OF CONTENTS

Contents Page

LIST OF TABLES

LIST OF FIGURES

LISTS OF ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
AME	Average Marginal Effects
ARI	Acute Respiratory Infection
BP	Bivariate Probit
CDC	Center for Disease Control and Prevention
CDF	Cumulative Distribution Function
DHS	Demographic Health Survey
ECD	Early Child Development
ECOSOC	Economic and Social Council
EHSD	Environmental Health and Sanitation Directorate
GBD	Global Burden of Disease
GDHS	Ghana Demographic and Health Survey
GHS	Ghana Health Service
GMHS	Ghana Maternal Health Survey
GSS	Ghana Statistical Service
HIRD	High Impact Rapid Delivery
HIV	Human Immune deficiency Virus
HWTS	Household Water Treatment and Storage
IGME	Inter- agency Group for Mortality Estimation
IV	Instrumental Variable
JMP	Joint Monitoring Program
LPM	Linear Probability Model
M.O.H	Ministry of Health
MDG	Millennium Development Goal

MLE	Maximum Likelihood Estimation
MLGRD	Ministry of Local Government and Rural Development
MSWR	Ministry of Sanitation and Water Resources
NGO	Non-Governmental Organization
ORS	Oral Rehydration Salt
ORT	Oral Rehydration Therapy
RC	Reference Category
SD	Standard Deviation
SDD	Statistics and Data Directorate
SDG	Sustainable Development Goal
SODIS	Solar Disinfection
SWN	Safe Water Network
U5MR	Under Mortality Rate
UN	United Nations
UNICEF	United Nation Children Fund
UVR	Ultraviolet Radiation
VIF	Variance Inflated Factor
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WSP	Water and Sanitation Program

CHAPTER ONE

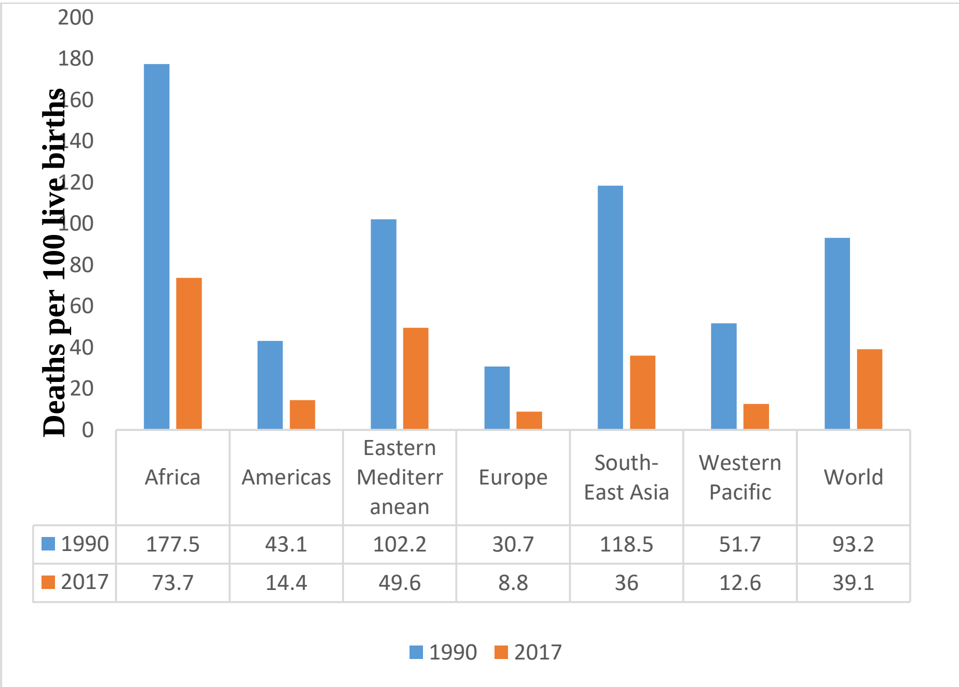
INTRODUCTION

Background of the Study

Health is an important form of human capital. It enhances workers' productivity by increasing their physical capacities, such as strength and endurance, as well as their mental capacities, such as cognitive functioning and reasoning ability. There are many plausible pathways through which health improvements influence the pace of economic growth and development. For example, better health directly enhances a longer lifespan, increases labor market participation and worker productivity (Strauss &Thomas, 1998; and Bloom & Canning, 2000).

Literature also suggests that ensuring optimal health among children is essential and instrumental in human capital formation and productivity, with the potential for economic returns. Better child health is a key determinant to achieve the quality of the future human capital of every country (World Bank, 2006). This is the main reason why child health has become a major concern for national and international stakeholders. However, high mortality and morbidity rate among children under the age of five years still remain a public health concern. persist in the developing countries. Although some interventions had been implemented with reasonable successes over the years. Still, the burden of child deaths remains immense.

Estimates developed by the UN Inter-agency Group for Child Mortality Estimation (UN IGME, 2019) revealed that 6.2 million of children and young adolescents died in 2018 alone, mostly from preventable causes. Of the 6.2 million deaths, 5.3 million (85 per cent) were children under five years, of which 2.5 million (47 per cent) occurred in the first month of life, 1.5 million (29 per cent) at age 1–11 months, and 1.3 million (25 per cent) at age 1−4 years (UN IGME, 2019). An additional 0.9 million deaths occurred among children aged 5−14 years (UN-IGME, 2019). Although, millions of children have better survival chances today than in 1990, children in Africa continue to face widespread regional disparities in their chances of survival. Africa remains the region with the highest under five mortality rates in the world, with an estimate of about 74 deaths per 100,000 births (Figure 1).



	Africa	Americas	Eastern Mediterranean	Europe	South-East Asia	Western Pacific	World
1990	177.5	43.1	102.2	30.7	118.5	51.7	93.2
2017	73.7	14.4	49.6	8.8	36	12.6	39.1

Figure 1: Global trends of under-five mortality between 1990 and 2017.

Source: UNICEF/WHO/World Bank (2018).

It is especially unacceptable that these children and young adolescents died, mostly from preventable or treatable causes like infectious diseases which could have been prevented. Among the underlying preventable pr treatable causes that predispose children under five to mortality and morbidity conditions is diarrhoea. In spite of the significant progress made over years, diarrhoea diseases still persists and contributes significantly to deaths among under five. According to a recent study by Van-Malderen *et al.* (2019), the major caused of deaths among children under five years in the low-middle-income countries. This explains that diarrhoea among under five remains a major public health concern especially in low and middle-income countries. Diarrhoea disease compromises many children under five lives by limiting their capacity and killing them. In 2016, diarrhoea was ranked the fifth leading cause of deaths among children under five causing about 446 000 deaths (Troeger et al., 2018). Although, death is the most serious of outcomes, diarrhoea is non-fatal illness and harmful because it also affects children school attendance and performance. It can affect a child's cognitive and physical health during the first 1000 days after conception, a main period of brain development.

Previous studies have identified child factors such as unsafe water, sanitation and hygiene (WASH) to be associated with diarrhoea (Esrey et al., 1991; Fewtrell et al., 2005; Fenta et al., 2019; Günther & Fink, 2011). Although, improving access to safe water, adequate sanitation and proper hygiene are on the frontline of efforts to achieve the anticipated 2030 Sustainable Development Goal 3 and 6. However, unsafe WASH is largely attributed to the cause of diarrhoea, a major cause of deaths among children under five. About 297 000 children under five die each year as a result of poor WASH (WHO/UNICEF, 2017). Africa remains on top (Figure 2.), as 46 deaths per 1,000 live birth is estimated (WHO, 2018).

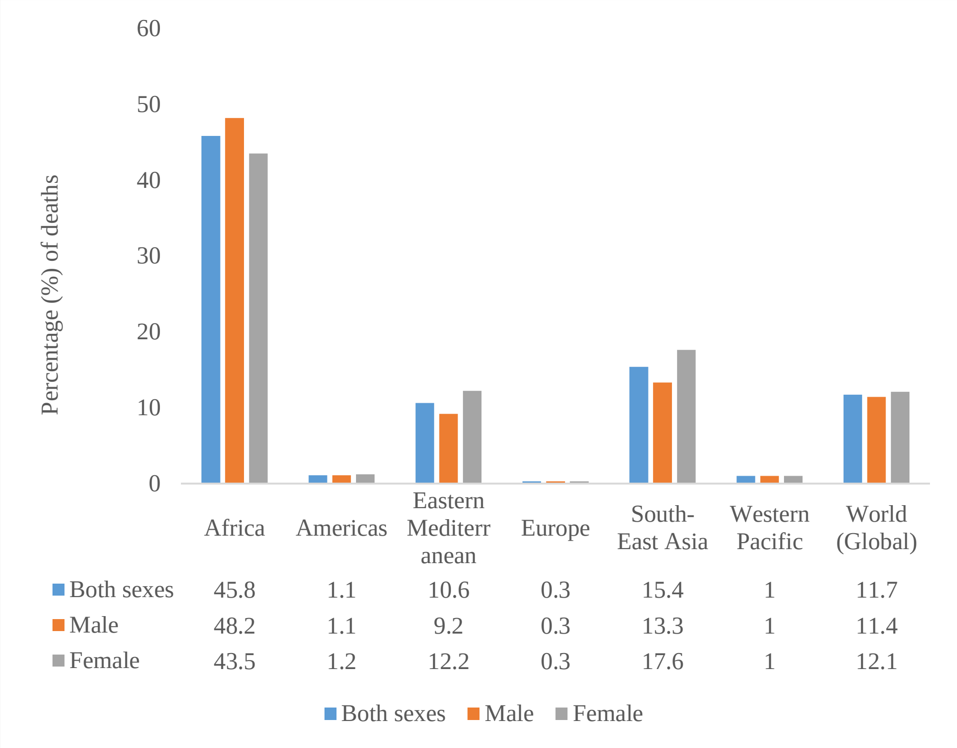


Figure 2: Distributions of under-five mortality due to unsafe WASH

Source: World Health Organization (2016).

Like other African countries, Ghana's under five mortality still persist than the average conditions prevail worldwide and this pose a public health challenge. Child under five mortality rates in Ghana are reported to be high (see Figure 3) and diarrhoea is a leading cause. Although, an assessment of national survey reports indicates that the prevalence of diarrhoea in 2008 was 19.8 % and dropped to 12 % in 2014 (GSS, GHS & ICF Macro, 2009; 2015), however, diarrhoea is still documented as one of the leading causes of childhood morbidity and mortality in the country (Tampah-Naah, 2019). Primary reasons for this include unsafe water and poor sanitation. Access to safe water in particular, still pose major challenges in Ghana. Even though, report indicates that more than 80 percent of Ghanaian population have been covered with regards to improved water (WHO/UNICEF/World Bank (2015), not all households have access to safe water, hence continue to rely on surface water and other unimproved water sources. Even households that have access improved water sources are still at a higher risk because improved water is not free from contamination and does not guaranteed safe water at the household level or point-of-use.

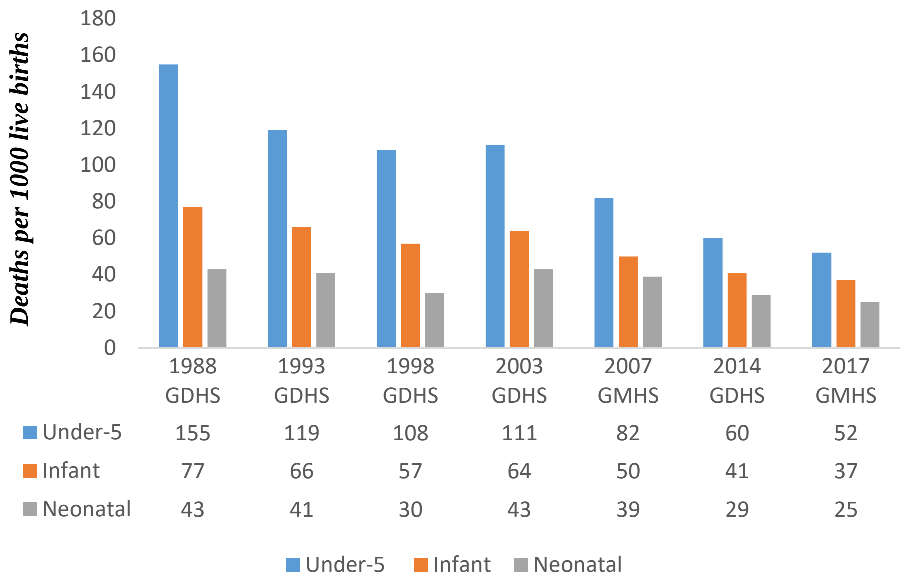


Figure 3: Trends of childhood mortality from 1988-2017 in Ghana.
Source: Ghana Statistical Service (2017).

The Ghana Multiple Indicator Cluster Survey (2017/2018) indicates that 78 % of drinking water at the point-of-use is contaminated (GSS, 2018). Another 20 percent of the rural population spend more than 30 minutes more than 30 minutes including queuing to access an improved source of drinking water. In addition, Safe Water Network (2015) discovered that about 29 % of all their hand pumps are broken and 49% partially functioning. Furthermore, according to Yeleliere, Cobbina and Duwiejuah (2018), about 60 percent of water bodies in Ghana are contaminated due to the soaring level of pollution from illegal mining (galamsey) and waste. Of great concern is that a recent study in Ghana indicates that even drinking water that is supplied from an "improved drinking water source increases the odds of diarrhoea by 1.3 times

(Nketiah-Amponsah & Afful-Mensah, 2017), and this is a critical issue of concern.

To overcome the difficulties in providing safe water, household water treatment has been advocated as a means to improve access to potable water and decrease the global burden of diarrhoea disease (Allawala, Barry & Kayani, 2017; Clasen *et al.*, 2007; Clasen *et al.*, 2015; Heitzinger *et al*., 2015; Tan & Capuno, 2012; Usman, Gerber &von-Braun, 2019; Wright, Gundry & Conroy, 2004; Zin *et al*., 2013). However, in Ghana, previous studies on the effectiveness of water quality interventions in reducing diarrhoea failed to consider the relative importance of household water treatment. For this reason, little is known in Ghana, leading to low uptake and use, especially among rural population who are more at risk of water borne disease. It is difficult to identify the population that benefit most from the potential effect of the intervention. It is against this backdrop in literature that, the current study examined the effect of household of water treatment on under five diarrhoea in Ghana.

Statement of the Problem

Improving access to safe water, adequate sanitation and proper hygiene are on the frontline of efforts to achieve the anticipated 2030 Sustainable Development Goal 3 and 6. Notwithstanding the numerous benefits associated with access to safe water, particularly at the household level, unsafe drinking water remains a big issue of concern in Ghana, where waterborne diseases, including diarrhoea cause a great harm among children under five. Although some progress have been made in the area of water delivery to more than 80 percent of the population in Ghana (WHO/UNICEF/World Bank, 2015), access to safe drinking water remains a major social problem which in essence has implications on the health of the people (Abbam & Carsamer, 2017).

Studies have argued that access to improved water does not necessarily guaranteed safe water at the point of use since improved water from source can be contaminated during transportation and handling (Pickering & Davis, 2012; Shaheed, Orgill, Montgomery, Jeuland & Brown, 2014). Households water treatment methods have been found to be more effective in improving household health than other types of interventions, such as treating water at the point of collection or at the source (Clasen & Mintz, 2004; Padilla, 2012; Sobsey *et al*., 2008). It has been reported that treatment of water at the household or point-of-use before using, is an effective intervention in achieving better child health in lower/middle income countries where access to safe water is limited. Studies have shown that household water treatment effectively improve drinking water quality and can reduce diarrhoea and related morbidity and mortality diseases (Allawala, Barry & Kayani, 2017; Clasen, Schmidt, Rabie, Roberts & Cairncross, 2007; Clasen *et al.*, 2015; Fewtrell *et al.*, 2005; Heitzinger *et al*., 2015; Tan & Capuno, 2012; Wright, Gundry & Conroy, 2004); Zin, Mudin, Myint, Naing & Sein, 2013).

However, the link between household water treatment and diarrhoea has not been extensively investigated and tested econometrically in Ghana. Despite there are a lot of studies the association between water quality and under five diarrhoea reduction in Ghana (Agbadi, Darkwah & Kenney, 2019; Armah *et al.*, 2018; Cha *et al.*, 2015; Dekoleadenu, 2015; Essilfie, Padi & Addor, 2017; Nkansah, 2014; Nketiah-Amponsah & Afful-Mensah, 2017; Osumanu, 2007; Quinn, 2009). Majority of these studies mainly focused on improved water indicator rather than household water treatment. Meanwhile, in Ghana, evidences indicate that improved water does not guarantee reductions in diarrhoea and related diseases. For example, Nketiah-Amponsah and Afful-Mensah (2017) revealed that drinking from improved sources was found to increases the risks of diarrhoea disease among children under five by 1.3 times. Also, Fielmua, Akudugu and Dugle (2019) found that provision of improved water does not guarantee reductions in diarrhoea diseases and improvements in livelihoods. Therefore, this study seeks to unravel the effect of household water treatment on child under five diarrhoea for policy purposes in Ghana.

Purpose/Objectives of the Study

The main purpose of the study sought was to examine the effect of household water treatment on under five diarrhoea in Ghana.

Specifically, the study sought to:

1. Assess the effect of source of drinking water on child diarrhoea status.
2. Examine the effect of treating water at household level on child diarrhea status.
3. Investigate the effect of household sanitation facilities on child diarrhoea status.

Hypotheses of the Study

This study sought to test the following hypotheses.

1. H_0: Improved water has no significant effect on diarrhoea reduction.

   H_1: Improved drinking water source has a significant effect on diarrhoea reduction.

2. H_0: Treating water at the household level has no significant effect on diarrhoea reduction.

   H_1: Treating water at the household level has a significant effect diarrhoea reduction.

3. H_0: Improved sanitation facility has no significant effect on diarrhoea reduction.

   H_1: Improved sanitation facility has a significant effect on diarrhoea reduction.

Significance of the Study

Firstly, the conception of the different approaches in the literature, have demonstrated clearly that, differentiated alignments for WASH service and their potential health gains in terms of reducing diarrhoea have allowed literature to be interrogated in a more meaningful way. In this regard, the researcher was better able to appreciate the motivating forces behind critical review of underlying assumptions and explains how different specific policy choices are suggested. As a result, the study linked other measures of household level, such as treatment of water to diarrhoea.

Another contribution of this thesis has been the potential for appropriate designed intervention to reduce risk of diarrhoea, therefore, this study contributes to knowledge in terms of the effect of household water treatment on diarrhoea reduction. Again, this study has contributed to knowledge in the application of two distinct methodologies to provide insight into the research questions. As stated earlier, several studies have reported directly on measuring the impact of improved water supply without addressing the possible endogeneity. The majority of the studies measure the impact of water on diarrhoea through the conventional Logistic and Probit models.

In addition, in 2014, the Government of Ghana through the Environmental Health and Sanitation Directorate (EHSD) previously in the Ministry of Local Government and Rural Development (MLGRD) and now in the Ministry of Sanitation and Water Resources (MSWR) with support from UNICEF, initiated a policy under the theme "Household Water Treatment and Safe Storage (HWTS)" across regional, district, and community levels. This policy aimed to contribute to a significant reduction of waterborne illnesses, particularly among susceptible communities, by encouraging household water treatment and safe storage as a key element of the community-based environmental health programs (Safe Water Network, 2014). Hence, this study would benefit to contributes to knowledge on a wide-scale use of household water treatment for the ultimate health gain in terms of diarrhoea reduction. The study would also serve as a useful academic material and adds to existing knowledge.

Scope of the Study

This study was conducted in Ghana and the dataset for the analysis were obtained from the sixth round of the Ghana Demographic Health Survey (GDHS), 2014. The study also used diarrhoea status among children under five years old as health outcome or depend variable, while improved water supply, improved sanitation facility and household treatment of water were the main explanatory variable. Again, the probit model and endogenous treatment effects model were used to test the hypotheses. The latter used to complement the probit model to help address the possible endogeneity problems, since one cannot obtain accurate estimates using conventional probit if there an unobserved variable that affects both the treatment and the outcome variables.

Limitations of the Study

There are limitations in the secondary data that were collected which may restrict the ability to draw general conclusions, but however do not affect the quality of the work. Firstly, it is anticipated that, employing the population-based data such as the GDHS for this study have limitation in terms of the inclusion of some equally important determinants of under-5 diarrhoea. This study may limit the definition of inequality in that the DHS records the type of drinking water and toilet facility for the entire household, but not for the individual, hence there may be an implicit disparity which is covered. In the same, the diarrhoea variable measured in the DHS is subject to biases in reporting. Since, the mother's responses to the child's question as to whether the child had diarrhoea in the two weeks prior to the interview was based on recalling, it suffers from uncertainty about the shared significance. Apart from these few limitations that could be the basis for further research, the results of the current study are still valid and could be used as the basis for policy formulation.

Organisation of the Study

The study is organised into five main chapters. Chapter One, the introductory chapter describes the background to the study, the research problem, study objectives and hypotheses, significance of the study, scope and limitation of the study. Chapter Two reviews related theoretical and empirical literature appropriate to this study while the research methods used in this study is discussed in Chapter Three. The research results are discussed in

Chapter Four. Finally, the overview of the study, conclusions, recommendations and suggestion for future studies are presented in in Chapter Five.

CHAPTER TWO

LITERATURE REVIEW

Introduction

From theoretical and empirical perspectives, water supply, household water treatment, sanitation, and hygiene have health gains benefits. Consequently, the comprehensive aim of this chapter is to present the review of the relevant literature on the relationship between water supply, treatment of water in homes, sanitation, hygiene and child health. Again, this chapter explores the theoretical expositions of child diarrhea and starts with the definition of health with the concept of child diarrhea through to water, sanitation and hygienic practices as well water treatment of water. The second section looked at the theoretical expositions underpinning the study. Finally, the empirical evidences with greater prominence on water supply, household water treatment, sanitation, hygienic practices as interventions for diarrhoea reduction.

Definition of Health

From antiquity, health has been understood as a physical or mental state in terms of the presence or absence of diseases. However, this definition is a key challenge in the present time and society since it does not fit in explaining how to establish social welfare facilitate, encourage, and secure individual autonomy and dignity. In the modern understanding of health, Dr. Andrija Štampar, one of the founders of the WHO and prominent scholars in the field of social medicine, public health proposed a definition of health and it became official in WHO Constitution at the time of its commission in 1948. Therefore, the generally accepted definition of health is referred to as "state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity". All contemporary concepts of health recognize health for this definition as more than the lack of disease, meaning the individual's maximum ability to self-realize and self-realize. This should balance the internal forces and opportunities of humans with the sense of enjoyment or discontent in their relationship with the setting.

Children

National Research Council (2004), the term "children" is generally use to refer to the ages between birth and 18 years of age. However, for the tenacity of research, children can be classified into different age groups or categories. For example, according to the World Bank three life cycle stages of the essence of Early Childhood Development (ECD) evaluation programs: First stage in pre-school for children under five or six years, the second stage at school age while the last stage been adulthood. The rationale behind this classification is used to assess the effect of the ECD programs in the short, medium and long term, respectively. Because in terms of a child's growth, the first five years are very crucial for essential growth takes place in all fields. For this reason and for the purpose of this study, all childcare and evaluation within the first phase of the life cycle (i.e. Preschool age group) will be restricted to children under five years.

Children's Health

World Health Organisation (WHO) has three separate concepts on child health. Firstly, "health conditions" reflecting the physical health status of the child; secondly, "functioning" emphasizing how health impacts the daily life of the child and, thirdly, "health potential" capturing the growth of resources and beneficial elements of the child. On the other hand, National Research Council (NRC) defined children's health as the extent to which individual children or groups of children are able or enabled to (a) develop and realize their potential, (b) satisfy their needs, and (c) develop the capacities that allow them to interact successfully with their biological, physical, and social environments (NRC,2004).

The quality of the future human capital of each country is mainly dependent on the children. (World Bank, 2006; Agyemang, 2013). Therefore, priority should be given to enhancing the health status of children, particularly those under the age of five since; it produces a social and financial return. This is to be explained that globally children are the foundation for a better future because of the fact that preservation of the current human race depends on better health of children. Therefore, it should be a major issue of all societies to ensure their good growth and development. This study is inspired by the fact that newborn children are especially susceptible to diarrhea and other infectious diseases that can be avoided or handled efficiently.

Overview of Child Health Interventions in Ghana

Children's health and well-being are essential not only as a reflection of the present health status of people and the country as a whole, but also as a predictor of the next generation's health. The early stage of childhood is a critical period for the development of human and social capital, and is therefore decisive in preparing future societies to be prosperous, sustainable and inclusive. This explains why many of the targets 3.1 of the sustainable development goal 3 explicitly directs efforts to ensure that child's health is enhanced. In Ghana, a lot of interventions has been taken by the government of Ghana together with other collaborating nongovernmental organisations at all levels to ensure child survival and development in the country.

The government of Ghana implemented the High Impact Rapid Delivery (HIRD) approach in 2006 (MoH & GHS, 2006), child under five: 2007-2015 policy which included the measles campaign in Ghana (MoH & GHS, 2006); the mosquito bed netting; vitamin A supplement; measles vaccination; polio vaccination, deworming practices, exclusive breastfeeding, suitable feeding by HIV-positive mothers, diarrhoea zinc, malnutrition management, pneumonia antibiotics, oral rehydration therapy (ORT) and malaria-related anti-malaria medications were all interventions introduced to enhance the health of children (MoH & GHS, 2016).

Other policies comprise of the National Environmental Sanitation Policy by Ministry of Local Government and Rural Development as well the National Water Policy and National Health Policy by the Ministry of Water Resources Works and Housing and Ministry of Health respectively. All these policies were implemented to proposed enhanced a better child health outcome. The good news is that, since the beginning of these health interventions, child health in Ghana have improved. However, child health is a major challenge in Ghana (Adua, Frimpong, Li & Wang, 2017). In Ghana, diarrhoea disease associated with poor water and sanitation kills about 4,000 children under five (GSS, GHS & ICF International, 2015). Despite the country halved the proportion of the population without sustainable access to safe drinking water by 2015, in line with targets for water outlined in the Millennium Development Goals (MDGs), water access, affordability, and quality continue to be predominant concerns.

Diarrhoea: Causes and Burden

Causes of diarrhoea

Diarrhoea is one of the most common health complaints. Diarrhoea is a Greek term called "diarrhoia" meaning "flowing through". Diarrhoea is best defined as passage of loose stools often with more frequent bowel movements. Apart from this fairly simple definition, diarrhea means different things to different individuals. For instance, according to World Health Organisation (2016), diarrhoea is defined as the passage of three or more loose or liquid stools per day (or more frequent passage than is normal for the individual). Diarrhoea is caused by a variety of bacterial, viral and parasitic organisms and spread through contaminated food or drinking-water, or from person-to-person as a result of poor hygiene. Generally, children and young adolescents, especially, those under five years old are more vulnerable to small doses of pathogens compared to other members of the household due to their immune system (Black et al., 2013).

According to World Health Organisation (2015), diarrhoea is a leading cause of childhood morbidity and mortality worldwide, especially, among children under-five years (i.e. 0-59 months of age). This disease accounted for the deaths of 5.9 million children under-five years in 2015; that is translating to approximately 16,000 deaths every day. Most of these deaths occurred in the African region with mortality rate of above 100 deaths per 1,000 live births (UNICEF, 2015). Projections show that diarrhoea contributed to about nine per cent of all deaths among children under age five; thus, being the second highest cause of childhood mortality; and approximately 1,400 young children dying each day and 526,000 children per year worldwide (UNICEF, 2015).

Diarrhoea can range from a mild, temporary condition, to a potentially life-threatening one. As a result, it is generally categorised into three major kinds based on duration, resulting in acute watery diarrhoea, bloody diarrhoea and persistent diarrhoea (Frank-Briggs, 2012). Acute watery diarrhoea is a term which relates to diarrhoea that starts acutely, lasts less than 14 days (most episodes last less than seven days) and includes the passage of frequent loose or watery stools without noticeable blood. There may be vomiting and there may be fever. Acute watery diarrhoea causes dehydration and it also leads to malnutrition, especially, when the intake of food is reduced. Acute watery diarrhoea can cause death when it is dehydrated and the pathogens responsible for the acute watery diarrhoea include the bacteria Rotavirus, V. Cholera, and Escherichia coli.

The bloody diarrhoea (i.e. dysentery or Shigella), is the prevalent pathogen because the stool of the child is generally followed by blood. Moreover, persistent diarrhoea starts acutely, but lasts exceptionally long (at least 14 days) and is prevalent among people with HIV / AIDS. The episode can either start as a watery or dysentery diarrhoea and frequent marked weight loss. In addition, the volume of diarrhoea stools can be high, with a danger of dehydration. It is worth noting that persistent diarrhoea has no single microbial cause; pathogens such as enter adherent E. The function of coli, Shigella and Cryptosporidium may be higher than that of other agents.

However, persistent diarrhoea should not be confused with chronic diarrhoea due to non-infectious causes such as gluten sensitivity or hereditary metabolic disorders, which is recurrent or long-lasting (Frank-Briggs, 2012). Other forms of diarrhoea include chronic, secretory, osmotic and inflammatory diarrhoea. Quite often, the episodes of diarrhoea are characterised by weight loss or dehydration due to the large stool volumes (Schiller *et al*., 2014). According to Schiller *et al*. (2014), chronic diarrhoea is of longer duration often lasting for more than four (4) weeks. As diarrhea becomes chronic, it is less likely to be due to infection; duration of 1 month seems to work well as a cut-off for chronic diarrhea. There is no known cause for chronic diarrhoea and does not respond to a particular form of treatment (Schiller *et al*., 2014)

Burden of Diarrhoea

Diarrhoea has been ranked among the ten causes of death and disability-adjusted life-years (DALYs) among all ages, and one of the top five causes death and DALYS for children under five years old. In spite of the fact that a recent study indicates that the fear or tragedy of death from acute diarrhoea decreases globally each year (Wierzba & Muhib, 2018), diarrhoea disease is still the second leading causes of morbidity and mortality among children and young adolescents in the world. For instance, according to World Health Organization (WHO), diarrhoea is responsible for around 525,000 (8%) deaths among children.

The United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME) revealed that 6.3 million of children and young adolescents under age 15 died in 2018 alone, mostly from preventable causes such as diarrhoea. The vast majority of these deaths (5.4 million) were children under five years, including, 2.5 million deaths occurring in the first month of life, 1.6 million in 1-11 months and 1.3 million between 1-4 years. The report further emphasised that these deaths mostly occur in Africa and Asia with 50 percent of under five deaths occurring in sub-Saharan Africa (SSA). Meanwhile, the UN Department of Economic and Social Affairs, Population Division (UN-DESAPD) the sub-Saharan Africa (SSA) region consists of 24 percent of the worldwide under five population (UN-DESAPD, 2017).

Apart from the fact that non-fata diarrhoea causes severe mortality among children diarrhoea also places a heavy tension on communities, particularly, marginalized children under five years in developing countries. Though, diarrhoea is ranked as the second leading cause of both mortality and morbidity, its impact is not limited to, health; with continued high attack rates. Those infected with the human immunodeficiency virus (HIV) or who developed, acquired immunodeficiency syndrome (AIDS), can have prolonged, severe and life-threatening diarrhoea (Hayes 2003). Moreover, diarrhoea is both a cause and effect of malnutrition as children who often suffer from diarrhoea have been found to have an underlying malnutrition.

Additionally, evidence has shown that children with diarrhoea are usually 24 months old and 1.0 cm shorter (Lee *et al*., 2012). As Victora *et al*.

(2010) emphasised, diarrhoea illnesses also contribute to child malnutrition and this is critical completely, especially if height not gained during first years of life since linear deficits in early childhood can be seen as markers of human potential lost. Moreover, diarrhoea is a distinct cause of impaired physical development and cognitive function, decreasing infection resistance, and possibly long-term gastrointestinal disorders and this in turn adversely affect school attendance and performance (Centre for Disease Control and Prevention 2015). Although epidemic diarrhoea, such as malaria and shigellosis (bacillary dysentery), is well recognised for the effects of diarrhoea, especially in emergency environments (Hunter 2003).

The immediate risk of diarrhoea, dehydration is a loss of liquids and electrolytes which in turn causes fast electrolyte and water loss with subsequent dehydration and death if the liquids are not replaced. According to Guarino, Guandalini and Vecchio (2015), the severity of diarrhoea illnesses is often dehydrated where moderate dehydration is characterised by thirst, eyes sunken, irritability, and skin elasticity diminished, while the symptoms of mild dehydration and severe dehydration involved pale skin, shock and altered consciousness. With regards to the enormous economic burden, Buono, Mathur, Averitt and Andrae (2017) signposts that diarrhoea disease leads to loss of time at work, school and other productive activities as well as millions of dollars in expenditure on prevention and treatment.

Overview of Child Diarrhoea in Ghana

The population of Ghana is approximately 30 million people with urban and rural populations of 56 percent and 44 percent respectively. Given this population of Ghana, children under five years in the country constitute about 15 percent (GSS, 2019). This age group of children represent the future of the country, as World bank (2006) clearly noted, however, majority of these children die from diarrhoea illnesses associated with inadequate and poor water supply each year. Despite the substantial interventions that has yielded positive health results, diarrhoea remains one of the leading causes of morbidity and mortality among children under five years old. In 2009, Ghana Health Services (2009) listed the top twenty causes of morbidity for all ages between 2006 and 2009 diarrhoea ranked fourth. The same diarrhoea illnesses was listed 4th on Ghana's top ten diseases cause for all ages in 2009. This is to explain that the improvement in the health outcomes cannot be attributed to under five mortality as diarrhoea rates are reported to be high in Ghana.

The World Health Organisation (WHO) revealed that children under five years are the specific risk groups that diarrhoea greatly suffer from the bout of diarrhoea with the highest prevalence occurring among children aged 12–23 months (16.8 percent) and also it is higher among males (13.1 percent) than in females (10.2 percent). A study in Ghana by Anyorikeya *et al.* (2016) estimated 113,786 cases of diarrhoea in 2011 with 354 deaths recorded due to severe dehydration for children under five years within the 2011-year period. This study further reported 2,318 diarrhoea cases in 2013. Also, a study in Central region, by Asamoah *et al*. (2016) on diarrhoea morbidity pattern reported a total case of all morbidity from 2008-2012 to be 7,642,431 and diarrhoea diseases formed 4% (306854/7642431) of this total morbidity.

The Ghana Health Services (GHS) report (2018) revealed outpatient due to diarrhoea cases in the country from 2015-2017 and 1,515,189 were recorded in 2015; 1,570,557 in 2016; and 1,429,990 in 2017 (GHS, 2018). In addition, the Joint Monitoring Programme report of the World Health Organisation (WHO) and United Nations Children's Fund (UNICEF) has revealed that more than 4,000 Ghanaian children die from diarrhoea every year (Who, 2018). The report indicates further that about 23 per cent of children suffer from stunting linked to diarrhoea-impaired growth and development that children experience from poor nutrition, repeated infection, and inadequate psychosocial stimulation. All these evidences of child diarrhoea in Ghana collaborate with a study conducted in 2016 among 46 African countries that reported Ghana is among 8 countries who are making very little progress towards reduction in under-five mortality (Kipp *et al*., 2016).

As mentioned earlier, studies in Ghana have shown that diarrhoea, a major cause of deaths among children under five years old is largely caused by lack of access to safe water supply, adequate sanitation and proper hygiene practices (Cha, et. al., 2015; Dekoleadenu, 2015; Essilfie, Padi & Addor, 2017). For instance, Armah (2014) has established that access to improved water sources significantly reduce water-borne diseases such as diarrhoea. However, there are still many people in Ghana who are not able to access safe at the household level. Even though in Ghana, about 87% of the population has access to safe drinking water the disparity in piped drinking water access between urban and rural communities is highly pronounced. Lack of access to safe or quality water is still one of the most challenging public health concerns in Ghana, especially at the rural areas, despite steady progress over recent decades. According to the Institute of Economic Affairs (IEA, 2015), about 65 percent of households in urban areas always has access to improved drinking water compared to 53 percent of rural households and this explains why childhood diarrhoea is prevalent at the rural areas.

Interventions to Prevent Child Diarrhoea

Quality of Water

Water and sanitation have been the subjects of considerable attention since 1980s as a result of the declaration by the United Nations General Assembly that access to improve the health of populations. Most of the research on the health impacts of water and sanitation projects has focused on the incidences of diarrhoea diseases, malnutrition, and mortality of young children, and evidence accumulated during the decade indicates that access to safe drinking-water is an essential intervention that can reduce diarrhoea disease risk. Likewise, absence of safe drinking water, continue to contribute significantly the diarrhoea risk, causing millions of under five deaths worldwide. Several studies like Esrey *et al.* (1991); Shier *et al.* (1996); Fewtrell *et al*. (2005); among others have examined the association between improved water and occurrence of diarrhoea and established that access to improved water lowers the risk of diarrhoea and other water related diseases such as bilharzia, trachoma, and intestinal helminthes.

For example, according to Esrey, Potash, Roberts and Shiff (1991), access to water for personal and domestic hygiene was important in reducing the rates of child diarrhoea by 26 percent. Also, Shier et al. (1996) opined that drinking from water that are supplied from improved sources lowers the pathogen counts, that pose threats to child diarrhoea. In addition, Mbonye (2004), analysed the likelihood of diarrhoea among children below two years in the Sembabule district of Uganda and established that drinking from unproved water sources such as rivers and streams are associated with 2.2 times higher likelihood of diarrhoea.

This emphasised is placed upon why the World Health Organisation and United Nations Children's Fund (WHO/UNICEF) Joint Monitoring Programme (JMP) for Water Supply and Sanitation, which monitors progress toward this MDG target, classifies a water source as "improved" if it has some measure of protection from outside fecal contamination such as a piped supply, boreholes, protected dug wells, protected springs, bottle water and rainwater. In contrast, unimproved source indicator includes unprotected dug wells, unprotected springs, water from tanker trucks or carts with small tanks or drums, and surface water. This was a core target of the Millennium Development Goals and currently the Sustainable Development Goals of halving the number of people without access to improved water sources with the aim that access to improved water supply is essential intervention that significantly improved human health and well-being.

However, studies have argued that improved supplies are frequently fecally contaminated, especially, in the developing countries. The indicator for improved water sources has been overemphasised, disregarding the fact that many continue to be contaminated, unreliable or unaffordable (Bain *et al*., 2014). Also, according to Shaheed, Orgill, Montgomery, Jeuland and Brown (2014a), access to an improved water source does not directly correlate with sustainable access to safe drinking water because an improved water source does not necessarily provide safe water at the point of use. In the case of Ghana, a recent study found that drinking from improved water sources rather increases the odds of diarrhoea by about 1.3 times (Nketiah-Amponsah & Afful-Mensah, 2017).

Sanitation Facility

Like quality of water, the significance of having adequate sanitation facilities like flush toilets, a type of improved sanitation facility using the WHO classification cannot be overemphasised. Access to proper sanitation facilities as well as ensuring sanitary conditions, including handwashing and safe disposal of human waste is vital interventions for breaking diarrhea transmission routes. Sanitation interventions are those some proper means of excreta disposal, usually latrines (either public or household) and these facilities are protective measures against diarrhoea disease; a leading cause of child under five mortality.

A large proportion of literature has established that sanitation is an additional factor that has the ability to reduce the toll of diarrhoea disease among children, especially, children under age five years old. Likewise, this explains that diarrhoea is transmissible and the disease can spread rapidly in areas with inadequate sanitation conditions. For instance, according to Boadi and Kuitunen (2005) children living in households without improved sanitation infrastructures suffer the risk of diarrhea compared to children with improved sanitation infrastructure such as flush or latrine. Also, Hutton and Chase (2016) established that inadequate sanitation leads to the transmission of pathogens through faeces and to a lesser extent, urine and this pose a greater risk of diarrhoea.

Moreover, a recent study by Wolf *et al*. (2018) found that sanitation interventions was associated with lower risk of diarrhoea morbidity by 25 percent, with evidence for greater reductions when high sanitation coverage age is reached. The study further emphasised that hygiene interventions promoting handwashing with soap also reduce the risk of diarrhoea by 30 percent. Literature also suggest that households sharing sanitation services with a number of five or more were discovered to have considerably greater levels of diarrhoea risks than those with private sanitation (toilet) facilities and this is due to the fact that shared toilets tend to be less hygienic. As Just *et al*. (2018), the risk of diarrhoea diseases increased with use of shared sanitation facilities.

However, the proportion of people using improved sanitation facilities in Ghana is low. As Mariwah (2018) emphasised, while inadequate water and sanitation, services have been implicated in a number of mortality and morbidity situations all over the world, the improvement in sanitation provision lags far behind that of water in Ghana. Despite, significant progress has been made since the MDGs era until now, millions of people in Ghana still faced with daily challenges accessing even the most basic of sanitation services. According to Ghana Statistical Service (GSS) and Macro International Inc (2015), in Ghana, while about 87 percent of the population has access to safe drinking water, only 15 percent has access to improved toilet facilities and about 20 percent practice open defecation. Ghana faces serious constraints to meeting the challenge of providing adequate and improved sanitation for its rural and urban inhabitants (Appiah-Effah *et al.*, 2019).

Relevance of Water, Sanitation and Hygiene to Child Health

Water and sanitation are essential resources needed to sustain life on earth. Numerous empirical studies have investigated the impact of water supply and sanitation infrastructure on human health. Access to water together with sanitation is essential for healthy development and growth of children all around the world. This emphasised is placed upon why adequate access to water and sanitation infrastructure is every child's right, as stated in the Convention on the Rights of the Child (United Nations, 1989). There is convincing range of empirical evidence that have linked reductions of the risk of diarrhoea diseases to improvements in water supply and sanitation infrastructures.

For instance, Esrey *et al*. (1990) as well as Fewtrell *et al*. (2005) suggest that access to improved drinking water supply substantially improves child health in terms of reducing the risk of diarrheal diseases. Also, Günther and Fink (2011) uncovered that household access to water and sanitation facilities strongly associated with lower risk of child mortality, diarrhea, and stunting. In the same vein, Kumar and Vollmer (2013) found a 2.2 percentage point reduction in diarrhoea incidence in under five children living in households with improved sanitation facilities. In addition, Usman, Gerber and von-Braun (2019) conducted a study on the impact of drinking water quality and sanitation on child health and the results show that access to uncontaminated household water and proper sanitation, including safe child stool disposal decrease incidence of child diarrhoea by 16 percent and 23 percent respectively.

With regards to hygiene and child health, promoting good hygiene behavior is crucial for realizing the full benefit of improved water supply and sanitation facilities, leading to reduction of child diarrhoea. Hygiene is a set of practice or change of behavior that people adopt to preserve their health. For instance, child stool disposal behavior of households is also an important factor of hygiene practices in the prevention of diarrhoea diseases. If children's feces are not contained or safely disposed of away from the living area, young children might be exposed to the stools through direct contact, which can cause diarrhoea via the hand-to-mouth pathway. Moreover, existing literature has suggested that promoting handwashing has shown the most success in achieving greater health impact. A recent review of hygiene practices by Cairncross *et al.* (2010) also indicated that handwashing with soap can result in a 48 percent diarrhea risk reduction in low- and middle-income countries where there is access to water.

The United Nations General Assembly in 2020, declared that "increasingly access to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and human rights" and openly called for actions leading to the provision of "safe, clean, accessible and affordable drinking water and sanitation together proper hygiene practice for all" (UN, 2010). However, access to safe water and improved sanitation remains insufficient in developing countries, particularly sub-Saharan Africa (SSA). As a result, children under five mortality is 14 times more than the developed regions (WHO, 2017). Ghana is no exception. This issue is compounded by the soaring level of illegal mining and lack of protection to most water sources.

which causes inadequate access to safe due to contamination.

Linkage between Water, Sanitation and Diarrhoea

Waterborne diseases, including diarrhoea are transmitted via the fecal-oral routes through fluids, hand contact, flies and food. Transmission routes include ingestion of contaminated food or water (through flies, poor sanitation, sewage systems and water treatment systems, poor personal hygiene, cleaning food with contaminated liquids) any direct contact with infected faeces, contact person-to-person and poor personal hygiene. Table 1 presents the potential transmission routes of pathogens and a broader classification of disease burden associated with unsafe and inadequate water supply. Diarrhoea disease is both a waterborne as well as a water-washed disease, and it can be caused by ingesting water contaminated with human and animal feces which contain pathogenic agents or ingesting these pathogens directly through various fecal-oral pathways. The latter is likely to occur when water availability is limited, which hinders proper hygiene practices (e.g., washing hands after defecation).

Table 1: Transmission Routes of Water-Related Diseases

Classification	Transmission route	Diseases transmitted
Waterborne	Through ingestion of pathogens in drinking water.	Diarrhoea diseases Enteric fevers, such as typhoid Hepatitis A

Water-washed	Through incidental ingestion of pathogens in the course of other activities; results from having insufficient water for bathing and hygiene	Diarrhoea diseases, Trachoma, Scabies
Water-based	Through an aquatic invertebrate host; results from repeated physical contact with contaminated water	Guinea worm, Schistosomiasis
Water-related insect vector	Through an insect vector that breeds in or near water	Malaria (parasite) and Yellow fever (virus)

Source: Bradley (1977).

In this regard, diarrhoea most prevalent diseases in the areas where availability of safe or quality water is a major challenge, and normally, under five children are the most vulnerable that suffer the severe risk of diarrhoea due to their immune system. For this reason, it is important to understand these diarrhoea transmission pathways in order to prioritize the appropriate prevention strategies and interventions. Therefore, Figure 4 presents the "F-diagram" illustrating the various pathways or route for diarrhoea transmission of diarrhoea and their interventions. Following the F-diagram, human and animal excreta are the primary sources of most disease-causing pathogens and these pathogens are passed from an infected host to a new one via various transmission routes.

As shown in Figure 4, the diseases are transmitted via the fecal-oral routes through fluids, hand contact, flies and food. This explains the importance of water and sanitation for safe removal of human feces as a primary barrier to prevent these pathogens from reaching the domestic environment. Several studies have revealed particular outcomes of measures aimed at reducing disease by improving drinking water and sanitation infrastructure, given these modes of transmission. As mentioned previously, Esrey *et al.* (1991) established that access to water, sanitation and hygiene equipment, prevent the incidence of a multitude of waterborne diseases, such as diarrhoea, intestinal helminths, guinea worm, skin illnesses, and trachoma by interrupting or decreasing the pathogenic agents, especially among children under five. Also, Bartram and Cairncross (2010) opined that unsafe water and insufficient sanitation associated with poor hygiene are key drivers of faecal-oral disease transmission, including diarrhoea illness.

However, it should be noted that household water treatment and good hygiene practices also serve as a secondary barrier to prevent the transmission of diseases-causing pathogens. For example, washing hands with soap after defecation and contact with child stools, and before eating and preparing food stop the transmission of disease agents because the source of the diarrhea pathogen is removed. Therefore, washing hands with soap can significantly reduce the burden of diseases associated with feces and polluted water. The secondary barriers are extremely important when sanitation services are inadequate and feces are disposed of into the domestic environment.

The secondary barriers highlights household water treatment as crucial interventions for diarrhoea prevention. This is because household or point-of-use water treatment as an intervention primarily reduces waterborne disease-causing pathogens from being transmitted. Treating water at the household level using different technologies such as boiling, filtering, or chlorinating, among others enhance the microbiological quality of drinking water and reduces the contamination from drinking water to food and the human body which causes diarrhoea disease transferred through liquids, hand contact, flies and food through the fecal-oral paths. Therefore, this study on household water treatment intervention by investigating its effectiveness on under five children diarrhoea reduction.

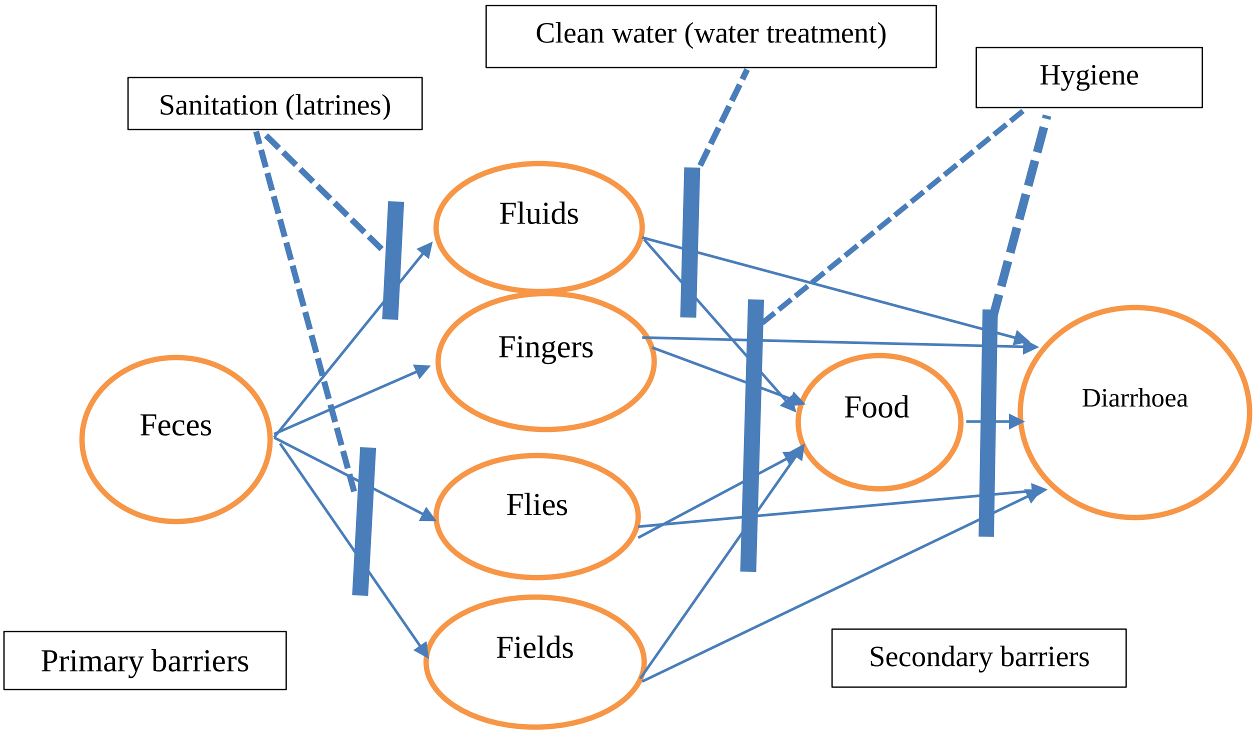


Figure 4: F-diagram of fecal-oral disease transmission and the barriers

Source: Wagner, Lanoix and WHO (1958).

Household Water Treatment for Diarrhoea Reduction

Providing sufficient safe water consistently to poor people is difficult, as proven time and again. Household water treatment has been proposed as a solution for populations without safe drinking water, and as a result, an intervention for diarrhoea prevention. Household water treatment is an intervention, that allows individuals to take full responsibility of their own water safety by treating and storing water themselves (WHO, 2013). Household water treatment is described as techniques used to make water safe before using it at the household level. These techniques require the use of a suitable treatment technology that includes a variety of alternatives and allow individuals or groups to decrease the pathogenic microbes in drinking water.

There is a wealth of evidence indicating that household or point-of-use water treatment lowers the risk of exposure to waterborne pathogens, in turn reducing child diarrhoea incidence. Household water treatment has been shown to be a sustainable solution for nations facing difficulties in supplying their individuals with secure drinking water, particularly developing countries. Studies such as. A historical study by Sobsey (2002) opined that household water treatment reduces the problem by removing, killing or inactivating microbial pathogens in the water. It can also minimize the risk of recontamination that even improved water supplies can present (Wright, Gundry & Conroy, 2004).

Other studies (Clasen et al., 2006; Clasen *et al*., 2007; Fewtrell *et al*., 2005) have shown that a suitable treating water in areas where there is no access to secure drinking water decreases the incidence of diarrhoea disease by 60 percent to 90 percent. A systematic review suggested that treating water with chlorine tablet at the point of use reduces not only the risk of Escherichia coli (E coli) contaminating storage water but also the risk of child diarrhea significantly in developing countries (Arnold & Colford 2007). In addition, recent studies indicate that households regularly using a household water treatment had reduced bacterial contamination, and had a higher reduction of diarrhoea (Allawala, Barry & Kayani, 2017; Geremew et al., 2018; 2019; Tan & Capuno, 2012;).

Appropriate Household Water Treatment Technologies

Appropriate technologies for household water treatment have been described as those techniques that are easily and cost-effective for populations in low-income countries to make use of readily accessible water resources safe (Hulland et al., 2015). Thus, technologies that are tailored to treat water at household level, while increasing the efficiency and quality of water to prevent the causing-pathogens for water related diseases. An appropriate household water treatment technologies should fulfill the fundamental features of: (1) being able to solve real problems and needs of unsafe water (2) being affordable to the majority of the intended user population (3) being simple in its design, operation and maintenance (4) not affecting negatively on the environment.

Numerous studies such as (Agrawal & Bhalwar, 2009; Geremew *et al*., 2019; Hulland *et al*., 2015), have shown that improving the microbiological quality of household water by point-of-use treatment reduces diarrhoea and other waterborne diseases. The most promising and accessible of the technologies for household water treatment are filtration with ceramic filters, chlorination with storage in an improvised vessel, solar disinfection in clear bottles by the combined action of UV radiation and heat, thermal disinfection (pasteurization) in opaque vessels with sunlight from solar cookers or reflectors and combination systems employing chemical coagulation-flocculation, sedimentation, filtration and chlorination. Also, the use of strain with cloth as well as let it stand and settle are household water treatment technologies mostly used in some part of developing countries such as Ghana, despite it is not regarded as a suitable treatment technique.

Boiling method

Boiling is the most prevalent and oldest technique used worldwide to treat water. Even though, promotion of boiling is not generally a common outbreak response strategy as it is energy intensive and does not provide residual protection of water during storage. Boiling or heating of water is effective in destroying all classes of waterborne pathogens and can be effectively applied to all waters, including those high in turbidity. However, the materials for boiling are often available in the household, and previous education campaigns mean beneficiaries are often aware of boiling. For this reason, the majority of households reported boiling. Other studies have suggested that if practiced efficiency, all classes of waterborne pathogens are known to deactivate, bacterial, including spores and protozoan cysts that have demonstrated resistance to chemical disinfection and viruses that are too small to be removed by microfiltration mechanically.

For instance, WHO (2014) recommends bringing water to rolling boil point temperature (100 0C) to guarantee that any pathogenic bacteria are prevented in water. Studies have also found that heating water has been shown to dramatically reduce pathogenic bacteria in drinking water for several hours. In addition, Agrawal and Bhalwar (2009) revealed that heating water reduces the formation of bacterial pathogens in drinking water to as 550C for several hours. Similarly, Brown and Sobey (2012) also discovered that boiling lowers the Escherichia coli's amount by (98%).

Chlorination

Chlorination is one of many ways of disinfecting water. Over a century ago, this method was first used and is still being used today. It is a chemical technique of disinfection that utilizes different kinds of chlorine or chlorine-containing substances to oxidize and disinfect what is going to be the source of drinking water. Chlorine is the most affordable, easily and widely used agent. It is highly effective against nearly all waterborne pathogens. Chlorination is commonly used to treat bacterial water and some viruses with chemicals such as water guard and water-safe tablets. Chlorine is widely used in emergency response due to its availability, ease of use, cost-effectiveness, ease of verification, effectiveness in inactivating bacterial and viral pathogens, as well as its maintenance in water treatment that protects against recontamination during water storage (Lantagne & Clasen, 2012).

Filtration

The use of filter papers is also an appropriate treatment method that helps in the removal of suspended material as it moves through porous material beds. According to Clasen (2009), the water filters was launched with a significant change in design that permitted the technology to function only with intermittent flow of water and then was reported by several studies. Treating water using water filters can remove microbes, organic matter, and turbidity. In addition, filtration methods are easy to manually clean to restore efficiency and flow rate when too much particles are accumulated.

Solar disinfection (SODIS)

Solar disinfection is a simple method that uses sunlight to inactivate pathogens to improve the quality of household drinking water. Solar disinfection, also known as SODIS, depends on sun energy to kill, particularly bacterial, pathogenic organisms. According to Dessie and Kishan (2014), solar disinfection is well known to inactivate bacteria and its effectiveness depends on local conditions to improve the microbial quality of drinking water using solar radiation. This includes exposing water in transparent plastic to complete sunlight depending on the intensity of exposure times vary from 6 to 48 hours. The advantage of solar disinfection is the result of its acceptability to users due to the minimal cost of water treatment, ease of use and minimal change in water taste and is proven to reduce bacteria, viruses and protozoa.

Theoretical Framework

Although, there are several kinds of theories explaining health evaluation, this study focuses on Grossman (1972) model of demand for health and its extension model by Jacobson (2000). Also, given that the study attempts to household water treatment which is a defensive behaviour of households or individual against water contamination in order to maximize health utility in terms of child diarrhoea reduction, the Alberini et al. (1996) theoretical model of explaining defensive behaviour and illness treatment was applied as well.

Demand for Health Theoretical Model

The theory of demand for health as established Grossman (1972) supports the suggest that people tend to invest in themselves in different ways by enhancing their knowledge inventory to increase their productivity in the market and family sectors. According to Grossman (1972), individuals have an incentive to invest in formal education or on - the-job training to recognize the potential gains in productivity. Investment costs include direct layers on market products and the time-consuming opportunity cost to be withdrawn from competing uses. This model is appropriate for the study given that it differs from other forms of human capital.

Grossman’s (1972) theoretical model acknowledge the fact that individual demand their health with a stock his or her market and non-market productivity, while the total amount of time he or she can spend producing is determined by his or her health stock. He also noted that if the basic demand is good health, it would be logical to study medical care demand by building a model of health demand itself first. In addition, since the traditional demand theory assumes that goods and services purchased on the market enter the utility function of consumers, economist has stressed the demand for medical care at the expense of healthy demand.

Consequently, he observes that a new approach to consumer behavior distinguishes basic objects of choice called "commodities" or market goods. The model assumes that people inherit an original health inventory that is increasingly depreciating over time. He asserted that an individual's health could be improved by investing in health. Death happens when the health inventory drops below a certain level. Gross investments in health capital are made by functions of household production, the direct inputs of which include their own time, and the consumption of market goods such as medical care and housing. The production function depends on some environmental variables, the most important of which is the producer's educational level that influences the production process's efficiency. Also, the level of health of an individual is not exogenous but depends, at least in part, on the resources allocated to its production. In sum, he established that, consumers for three reasons demand health as follows:

1. It enters straight into the performance features of the consumer as a consumer commodity placed differently; sick days are a source of useless.
2. The complete quantity of time available for market and non-market operations is determined by health as an investment commodity.
3. A rise in health inventory decreases the time lost from these operations, and this reduction's currency value is an index of the return on health investment.

The Grossman's (1972) Models

As discussed above, the Grossman (1972) considers the inter-temporal utility function of a typical consumer and this is expressed as:

$$U = U(\emptyset_0 H_0, \ldots \emptyset_n H_n, Z_0, \ldots, Z_N) \quad 1$$

Where: H_0 is the inherited stock of health; the stock of health in the period 1; $\emptyset_0$ is the service until flow per unit stock; $h_1 = \emptyset_1 H_1$ is the total consumption of health service, Z_i is the total consumption of another commodity in the period i. The commodity Z_i may be viewed as an aggregate of all commodities besides health that enter the utility function in the period 1, whereas in the usual inter-temporal utility function n, the length of life as of the planning date, is an endogenous variable. In particular, death takes place when $H_i = H_{min}$. therefore; the length of life depends on the quantities of H_i that maximizes utility subject to certain production and resource constraints. By definition, net investment in the stock of health equals gross investment minus depreciation:

$$H_{1+1} - H_i = I_i - \delta_i H_i \quad 2$$

Where I_i is the gross investment and δ_i is the rate of depreciation during time period I. The rates of depreciation are assumed exogenous, but they may vary with the age of the individual. Consumers produce gross investments in health and the commodities in the utility function according to the following set of household production functions.

$$I_i = I_i(M_i, TH_i; E_i) \quad 3$$

$$Z_i = Z_i(X_i, T_i; E_i) \quad 4$$

From equation $(3a)$ and $(3b)$ above, M_i is medical care, is the input goods in the production of the commodityZ_i, TH_i is the time input in the gross investment function; $??_i$ is the time input in the production of Z_i and E_i is the stock of human capital. However, generally, medical is not the only market good in the gross investment because inputs such as housing, WASH, alcohol consumption among other influences one's level of health. Since these inputs also produce other commodities in the utility function, therefore, joint production occurs in the household.

The key aspect of this model is that, Grossman treats medical care as the most important market good in the gross investment function. It is also assumed that a shift in human capital changes the efficiency of the production process in the non-market sector of the economy, just as a shift in technology changes the efficiency of the production process in the market sector. Further, it assumed that all production functions are homogeneous of degree one in the goods and time inputs. Hence, the gross investment, production function can be written as:

$$I_i = M_i g(t_i; E_i) \quad 5$$

$$t_i = I_i(TH_i/M_i) \quad 6$$

Also, the model follows that the marginal product of time and medical care in the production of gross investment in health as expressed below:

$$\frac{\partial I_i}{\partial TH_i} = \frac{\partial g}{\partial t_i} = g^i \qquad 7$$

$$\frac{\partial I_i}{\partial M_i} = g - t_i g^i \qquad 8$$

However, from the viewpoint of the individual, both market goods and own time are scarce resources. Thus, the goods budget constraint equates the present value of outlays on goods to the present value of earnings, income over the life cycle plus initial assets (discounted property income).

$$\sum \frac{P_i M_i + V_i X_i}{(1+r)^i} = \sum \frac{W_i TW_i}{(1+r)^i} + A_0 \qquad 9$$

Where i=0 to n

From equation (6), P_i is the price of M_i; V_i is the price of X_i; W_i is the wage rate; and TW_i is hours of work. Also, A_0 is the discounted property income; while r presents the interest rate. The time constraint requires Ω, the total amount of time available in any period, must be exhausted by all possible uses, such that:

$$TW_i + TL_i + TH_i + T_i = \Omega \qquad 10$$

Where TW_i= Hours of work; TL_i= Time lost from market and non-market activities due to illness or injury TH_i= Time input in gross investment function and T_i=Time input in the productions of Z_i. According to Grossman (1972), this equation 7 modifies the time budget constraint in Berker's (1964) time model. This explains that this if sick time were not added to market and non-market time, total time would not be exhausted by all possible uses. Therefore, Grossman's model assumes that TL_i is inversely or negatively related to the stock of health expressed as $\frac{\partial TL_i}{\partial H_i} < 0$. By substituting for TW_i from equation (7) into the equation (6), we obtain the following single "full wealth" constraint:

$$\sum \frac{P_i M_i + V_i X_i + W_i(TW_i) + TL_i + TH_i + T_i}{(1+r)^i} = \sum \frac{W_i \Omega}{(1+r)^i} + A_0 = R \quad 11$$

Equation 8 is full wealth equals initials assets A_0 plus the present value of the earnings an individual would obtain if he or she spent all of his/her time first term on the RHS. Part of this wealth is spent on market goods, part of it is spent on non-market production time, and part of it is lost due to illness. The equilibrium quantities of H_i and Z_i can now be establish by maximising the utility function given by equation 1 subject to the constraints given by equation 2, 3 and 8. Since the inherited stock of health and the rates of depreciation are given, the optimal quantities of gross investment determine the optimal quantities of health capital. As a result, the first-order optimality conditions for gross investment determine the optimal quantities of health capital is given as:

$$\frac{\pi_{i-1}}{(1+r)^{i-1}} =$$

$$\frac{W_i G_i}{(1+r)^i} + \frac{(1-\delta_i) W_{i+1} G_{i+1}}{(1+r)^i} + \cdots + \frac{(1-\delta_i)(1-\delta_{n-1}) W_n G_n}{(1+r)^n} +$$

$$\frac{Uh_i}{\lambda} G_i \frac{(1-\delta_i)(1-\delta_{n-1}) Uh_i}{\lambda} G_n \quad 12$$

$$\pi_{i-1} = \frac{P_{i-1}}{g - t_{i-1} g} = \frac{W_{i-1}}{g} \quad 13$$

Equation (9-10) represents the equilibrium condition. The new symbols in these equations are: $Uh_i = \frac{\partial U}{\partial h_i}$ the marginal utility of healthy time, λ, the marginal utility of wealth $G_i = \frac{\partial h_i}{\partial H_i} = -\left(\frac{\partial TL_i}{\partial H_i}\right)$, the marginal product of the stock of health in the production of healthy time and π_{i-1}, the marginal cost of gross investment in health in period I-1.

Equation 2 through to 10 completely determines the optimum amount of a capital good at time 1 that can be purchased and sold in a perfect market. Health capital stock cannot be sold as it is imbedded in the investor, like knowledge capital stock. Therefore, this means that no negative gross investment can occur. Although capital sales are excluded, provided that gross investment is positive, the cost of capital to the user has to be equal to the value of the marginal product of the stock in balance.

Overview of Jacobson (2000) Theoretical Model

Given that this study focused on child health outcome which is under five diarrhoea, the exposition of the Grossman (1972) expanded model by Jacobson (2000) was considered as well. Even though, the Grossman (1972) theoretical model provides useful contributions to clarify health-related behaviors and variations in the use of health and health care, it has been used as a health producer on the individual only. This means that both the original Grossman (1972) model can only be used to analyse the health of adults, not the health demand of children and their health care utilisation. As a result, Jacobson (200) based on the concept of concentrating on different levels of the family to derive the demand for health or medical care model. For this purpose, a careful examination of the parents-child model specification mathematical derivations of the extended Grossman model by Jacobson (2000) was examined. According to Jacobson (2000), the expanded Grossman model-the parent-child family specification is based on a prevalent preferential family behavior model, the instant family function (strictly concave) can be written as:

$$U = u\left(H_m,\ H_f, H_c, Z\right) \qquad 14$$

Where time subscript is omitted in order to make things easier, the notations; u is the family utility in period t, H_m, H_f, and H_c are husband (male), wife (female) and child health respectively, and Z is a vector of commodities consumed. The depreciation in male (δ_m) and female health (δ_f) may be offset by gross investment in male(I_m) and female (I_f) health, respectively, where $i = m, f$ according to the production function:

$$I_t = I_t(M_t, (h_{Hi}; E_{H,i}) \qquad 15$$

Where the production function is assumed homogeneous of degree one in goods and time inputs. M_t indicates market goods used in the production of male and female health. Time is used in the production of health is indicated by$h_{H,}$. The first subscript denotes what is produced; male (H_m) or female (H_f) health, the second subscript denotes what is the producer; the husband (m) or the wife (f). $E_{H,i}$ is the efficiency parameter indicating individual outputs. According to Jacobson (2000) model, the family also produces other commodities in the production function and this is given as:

$$Z_i = Z_i(X_i, h_{z\,i}, E_{z,i}) \qquad 16$$

Where X_i is a market good and $E_{z,i}$ is the parameters for efficiency. Similarly, the husband and wife net investments in health are:

$$\frac{\partial H_i}{\partial t} = I_i - \delta_i H_i \qquad 17$$

Also, according to the motion, the child health is assumed to be developed over time expressed as:

$$\frac{\partial H_c}{\partial t} = I_c - \delta_c H_c \qquad 18$$

This is produced by the child's parents by the use of market goods M_c and parental time $h_{H\,c,m}$ and $h_{H\,c,f}$ respectively according to the production function:

$$I_c = I_c\left(M_c, h_{H\,c,m}, h_{H\,c,f}, E_{H,m}, E_{H\,,f}\right) \qquad 19$$

The development of family wealth, which depends on parental human capital, wage rate and market interest rate follows

$$\frac{\partial w}{\partial t} = rW + w_m\left(H_m, E_{w,m}\right)h_{w,m} + w_f\left(H_{f,}E_{w,f}\right)h_{w,f} + B - p\left(M_m + M_f\right) - qX \qquad 20$$

Where $w_m\left(H_m, E_{w,m}\right)$ and $w_f\left(H_{f,}E_{w,f}\right)$ are the husband's and wife's wage rate of labour market earnings rates of return on human capital respectively. $E_{w,m}$ $(E_{w,f})$Is the husband's (wife's) level of education and on-the job training, and his (her) amount of time spent in the market work, or is the market interest rate, w is the wage rate, B is transfer, and p and q are the prices of medical care M and other goods X respectively. As clearly noted by Jacobson (2000), health affects the market income in two ways: through its effect on the wage rate; and through its effect on healthy time available for market work. From equation 3 an individual's productivity in market work is determined by his or her amount of health capital and level of education and the on-the-job training, implying that $w_m\left(H_m, E_{w,m}\right)h_{w,m} + w_f\left(H_{f,}E_{w,f}\right)h_{w,f}$ can be thought as the labour market earnings rate of return on human capital. The time restriction for each parent (husband and wife, respectively) then becomes

$$\Omega_i = h_{w,i} + h_{z,i} + h_{Hm,i} + h_{Hf,i} + h_{s,i} + h_{sc,i} \; i = m, f \qquad 21$$

Where $h_{sc,i}$ is the time used in taking care of the sick child for parent i, and where $\frac{\partial h_{sci}}{\partial H_c} < 0$ and $\frac{\partial^2 h_{sci}}{\partial {H_c}^2} > 0$. Thus, it is assumed that parents are taking care of their sick children. In reality, however, they may be other alternatives. The family problem will now be extended to choose the conduits of M_m, M_f, M_c, and z in order to maximize utility:

$$MaxU = \int_t^T e^{-\theta t}\, u(H_m, H_f, H_c, Z$$

Subject to: $\frac{\partial Hj}{\partial t} = I_i - \delta_j H_j$ for $j = m, f, c$

$$\frac{\partial w}{\partial t} = rW + w_m(H_m, E_{w,m})h_{w,m} + w_f(H_{f,}E_{w,f})h_{w,f} + B - p(M_m + M_f) - qX$$

$$\Omega_i = h_{w,i} + h_{z,i} + h_{Hm,i} + h_{Hf,i} + h_{s,i} + h_{sc,i} \; i = m, f$$

$$H_j(0) given\ for\ j = m, f, c$$

$$H_j(T) \le H_{min} for\ at\ least\ one\ of\ j = m, f, c$$

$$w(T) \ge 0, W(T) * \lambda w(T) = 0$$

$$T\ free\ and\ X, M_j \ge 0\ all\ t[0, T], j = m, f, c \qquad 22$$

Where U is the family's intertemporal utility function, that is; the discounted value of the family's lifetime utility, discounted by the family rate of time preferenceθ. $\frac{\partial Hj}{\partial t}$ and $\frac{\partial w}{\partial t}$ are the equations of motion for the state variable H and W, respectively, and the time restriction. H_{min} is the minimum individual's death stock of health capital. The individual dies when health passes below some level H_{min}, which determine T (time of death). T in this case, is the "lifetime" of the parent- child family. The family member dies when parents and /or child no longer has health status greater than H_{min}. Also, it should be noted that the family is free to borrow and lend capital at each period, but the bequest (WT) cannot be negative. Therefore, setting the langrangian and solving the maximization problem in the equation (9) gives the marginal condition in equation (10) as;

$$\frac{\partial u/\partial H_i}{\partial u/\partial H_c} = \frac{\pi_i\left[\delta_i + r - \frac{\frac{\partial \pi_i}{\partial t}}{\pi_i}\right] - [-\frac{\frac{\partial w_i}{\partial H_i}}{h_{w,i}} - \left(\frac{\emptyset_i}{\lambda_w}\right)\left(\frac{\partial h_{s,i}}{\partial H_i}\right)]}{\pi_c\left[\partial_c + r - \frac{\frac{\partial \pi_c}{\partial t}}{\pi_c}\right] - [-\left(\frac{\emptyset_m}{\lambda_w}\right)\left(\frac{\partial h_{sc,m}}{\partial H_c}\right) - \left(\frac{\emptyset_f}{\lambda_H}\right)\left(\frac{\partial h_{sc,f}}{\partial H_c}\right)]} \quad 23$$

Where λ_w and λ_H are costate variables, $\emptyset$ is the langrange multiplier for the time restriction, $\partial u/\partial H_i$ is the marginal utility of capital, $\frac{\partial w_i}{\partial H_i}$ is the marginal effect of health on wage, $\frac{\partial h_{sc,f}}{\partial H_c}$ is the marginal effect of the health of the child on the amount of time they commit to the sick child and π is the effective price of medical care goods and services (m_t). Jacobson (2000) concludes that, the net effective marginal investment benefit of child health is equal to the user cost of child health capital minus the marginal investment benefit of child health, which is the sum of the monetary value of the change in the time taken care of a sick child for father and mother, for the marginal change in child health, respectively. The child's lifetime usefulness of health can be obtained as:

$$\lambda_w = \frac{\lambda H_c}{\lambda_c} \quad 24$$

This implies that the family invest in child health until the rate of marginal utilities of (child's lifetime) health to the effective price of health for all family members is equal and equal to the marginal utility of wealth. The family will not try to equalize the amount of health capital between family members. Hence, rearranging equation (11) gives $H_c = \lambda_w \pi_c$. And this implies that poor families (where the wealth restriction is binding) value a marginal change in child health higher than rich families, and that families for whom the wealth constraint is not binding ($\lambda_w = 0$) has a zero-marginal utility of child health. It also means that a child with unhealthy parents may be expected to have reduced health compared to a child with healthy parents because money must be spent on improving the health of unhealthy parents in order to attain status in equation (10). This model has been able to offer a direct description of child health and how critical child survival is important to family resources, especially parental human capital and parental roles.

Theory of Defensive Behaviour and Illness Treatment

As established above, Grossman's (1972) theoretical is mostly used to analyse health care demand to reduce mortality and morbidity of diseases. However, in an attempt to evaluate the defensive behaviour of an individual against environmental contamination in order to maximize utility, the study mildly follows the model of defensive behavior and disease treatment as developed by Alberini et al. (1996). The model assumes that an individual derives utility from the consumption of a numerire good Z, normalized, with a price of one, leisure L while illness S causes disutility, thus express as:

$$U = U(Z, L, S) \qquad 25$$

$$U_X, U_L, > 0; U_S < 0,$$

From equation 1, time spend on illness S is modelled as a function if the exposure to contaminants C and averting or defensive behaviour to reduce the likelihood of the illness which explains the actual time T_d that the household spends on defensive activities (Alberini et al., 1996). The defensive activity T_d that household exhibit reduces the impact of the exposure to the contaminant, thereby affecting the household's well-being. Thus, the health production function can be specified as

$$S = S(C, T_d) \qquad 26$$

$$S_C > 0; S_{T_d} < 0$$

The household's budget constraint can then be specified as

$$Y + w(T - L - T_d - S) = Z + P_d \qquad 27$$

Where Y is total non-labour income, w is the wage rate, $T$is total time and P_d is the price of defensive activity. The first-order conditions for optimising the Lagrangian (ζ) can also be expressed as:

$$\zeta = \mathrm{U}\{\mathrm{Z}, \mathrm{L}, \mathrm{S}\ (\mathrm{C},\ T_d)\} + \lambda[Y + w(T - L - T_d - S) - Z - P_d T_d] \qquad 28$$

With respect to Z, L, and T_d are easily shown to be:

$$U_Z - \lambda = 0 \qquad 29$$

$$U_{L=}\lambda w = 0 \qquad 30$$

$$U_S \frac{\partial S}{\partial T_d} - \lambda\left(w\frac{\partial S}{\partial T_d} + P_d\right) = 0 \qquad 31$$

The optimal defensive behaviour derived from the first-order conditions is expressed as: $T_d * = T_d * (w, Y, C, P_d)$ 32

And this is therefore a function the wage rate, w, of non-labour, Y, of the cost of the defensive activity, P_d, and of the threat of the exposure to contamination C. In substituting equation 8 which is the optimal function of defensive behaviour into the equation 2 thus the health production function, S, we obtain:

$S = S(C, T_d *)$ 33

Where the last two equations explain the dose-response function and the defensive behavior function.

Empirical Literature

Several studies have used a variety of measures to analyse the effects of access to water, sanitation, hygiene as well as household water treatment and other socio-economic factors on the health outcomes of children, particularly, under five children. It gratifying to note that majority of the studies used child mortality, morbidity, or diarrhoea disease as the primary outcome variable as a measure of child health status. Therefore, this section will presents the review of empirical studies that examine the relationship between water, sanitation, hygiene as well as household water treatment interventions and child health, focusing on under five diarrhoea disease since it has been widely found to be a disease that often results from unsafe water, insufficient sanitation, and poor hygiene practices

According to a study by Esrey *et al.* (1991), access to improved water supply reduces the incidence of diarrhoea among under five children by 17 and 22 percent with access to adequate sanitation infrastructures. The same Esrey and other co-authors (1996) established that children living in households that have access to flush toilets decrease the risk of diarrhoea from 13 percent to 44 percent and access to latrines reduces diarrhoea by 8.5 percent. Further, the study found that access to good sanitation has greater health effects than access to good water. However, Gunther and Fink (2010) criticised the findings of Esrey *et al.* (1996) on the basis that they included only 8 countries out of the 63 countries with available DHS datasets during the

1995-year period. Contrarily to Esrey *et al.* (1996), Gunther and Fink (2010) used 172 datasets from 70 countries to analyse the effects of access to water and sanitation on child mortality and morbidity. The study established that access to improve water and sanitation reduces the incidence of diarrhoea among under five children by five percent 17 percent and also established that it reduces infant mortality from five percent to 20 percent.

In addition, Dasgupta (2004), used the health production model and employed the probit regression model in analysing the health damage from pollution that cause diarrhoea morbidity in the slum of Delhi. The study found that households with access to piped water are less likely to suffer the risk of diarrhoea disease compared to their counterparts. However, there was no significant effect of the existence of sanitation as well as household head education on diarrhoea reduction. In the same, a systematic review by Fewtrell *et al.* (2005) on the summary estimates of the efficacy of each type of intervention indicated that water quality interventions, particularly, point-of-use water treatment in decreases the rates of diarrhoea disease in the developing countries. The study further added that although water supply at source interventions lowers the risk of diarrhoea, the effect was seen primarily linked to water management in the household through hygiene interventions such as hand washing.

Moreover, Clasen *et al.* (2007) conducted a systematic review of interventions to improve water quality for the prevention of endemic diarrhoea. Using 30 studies and 38 intervention respectively for meta-analysis, the results showed that household water treatment is the most effective interventions to improve the microbiological quality of water and reducing diarrhoea. Household water treatment was considered to be extremely cost-effective in most and found to reduce the incidence of diarrhoea by 60 percent. Tan and Capuno (2012) used treatment effects model and instrumental-variable probit model on sub-samples of households with under five children by investigating the effect household water treatment and under five diarrhoea in Philippines. The findings from this study established that households that treats water prior to use at the household level likely to reduce the proportion of under five children suffering from diarrhoea by 4.26 percentage points. Onjala, Ndiritu and Stage (2014) examined the effect of households' characteristics and risk perceptions on their decision to treat/filter water as well as on their choice of main drinking water source in Kenya. They employed seemingly unrelated bivariate probit model in estimating household datasets from four cities in Kenyan and found that household water treatment reduces diarrhoea, however, household's decision to treat water before drinking correlates with household's wealth status and higher connection fees.

Zin *et al*. (2013) investigated the influencing factors for household water quality improvement for reducing diarrhoea in resource-limited areas. The study data from articles and reviews from relevant randomized controlled trials, new articles, systematic reviews and meta-analyses from PubMed, World Health Organization (WHO), United Nations Children's Fund (UNICEF) and WELL Resource Centre for Water, Sanitation and Environmental Health, and the results established that point-of-use water treatment (household-based) is the most cost-effective method for prevention of diarrhoea. further, chemical disinfection, filtration, thermal disinfection, solar disinfection and flocculation and disinfection were found to be the five most promising household water treatment methodologies for resource-limited areas. Clasen *et al.* (2015) examine the effectiveness of interventions to improve water quality for diarrhoea prevention and showed that household or point-of-use water treatment interventions using appropriate technologies such as disinfection products, chlorination products and filtration systems could be significant interim measures to tackle microbial water contamination at the point-of-use in order to improve the quality of drinking water until households can be reached with safe, reliable, piped-in water.

Ercumen *et al.* (2015), conducted a randomized controlled trial in rural Bangladesh to assess whether improving the microbiological quality of tube well drinking water by household water treatment and safe storage would reduce diarrhea in children less than 2 years of age. A sample of 1800 households with a child aged 6-18 months (index child) were randomly assigned into one of three arms such as chlorine plus safe storage, safe storage and control and also data collected on health outcomes. Taken together with this intervention, the results posited that safe storage alone or combined with chlorination, reduced heavy contamination of stored water. In addition, chlorine plus safe storage reduces child diarrhea by 36 percent in rural Bangladesh. Moreover, Allawala, Barry and Kayani (2017) conducted a study on diarrhoea diseases due to unsafe drinking water in Pakistan using a cross-sectional data from the Pakistan Demographic and Health Survey (PDHS) 2012-13 with a sample size of 13,409 of households. The study employed 2SLS model to examine the incidence of under five diarrhoea illness and found that households that reportedly treats water before drinking likely to reduce diarrhoea disease by 31.5 percent.

Cohen and Colford (2017) conducted a systematic review and a meta-analysis effects of boiling drinking water, a technology for household water treatment on diarrhoea and pathogen-specific infections in low- and middle-income countries using reported and calculated odds ratios (ORs) and random-effects meta-analysis. The study found that boiling water at the household level provides measureable health benefits for pathogens whose transmission routes are primarily water based. Doocy *et al.* (2018) evaluated the effectiveness of point-of-use water treatment in improving treatment of children affected by severe acute malnutrition (SAM) in Pakistan. Evidence from the findings established that recovery rates was 16·7 percent to 22·2 percent higher among children receiving water treatment compared with the control group, therefore, incorporating point-of-use water treatment into outpatient treatment programmes for children with SAM increases nutritional recovery rates.

Usman, Gerber and Von-Braun (2019). used primary household survey dataset and Escherichia coli microbiological water test to investigate the effect of drinking water quality and sanitation behaviours on diarrhoea incidence among under five children in Ethiopia's rural districts. The study employed different econometric models such as probit regression model, instrumental variable (IV) estimator and bivariate probit (BP) estimator and found that household water treatment and safe child stool disposal reduces under five diarrhoea incidence by 16 percent and 23 percent respectively. While, household use of pit latrine increases the risk of under five diarrhoea by 12 percent. Also, a recent study by Mengistie *et al*. (n.d) conducted randomized controlled to examine the effectiveness of household water chlorination (point-of-use water treatment) in reducing diarrhoea incidence among children under-five years of age in rural community of Eastern Ethiopia. A statistically significant reduction in incidence of diarrhea was found in the intervention group compared to the control. As result, the study recommends expanding access to household water treatment can help to substantially reduce child morbidity and achieve sustainability development goals.

In the context of Ghana, Quinn (2009) examined the likelihood of diarrhoea among Ghanaian under five children using 2003 GDHS and logistic regression model and revealed that household's access to sanitation infrastructure decreases the likelihood of diarrhoea. the study however, found access to piped water not significant in reducing under five diarrhoea and concluded that this could be the fact household or point-of-use water treatment was not considered in the analysis. To fill this identified gap in literature, the current study therefore examined the effect of household water treatment on under five diarrhoea in Ghana. Similarly, Dekoleadenu (2015) assessed the relationship between source of household drinking water and diarrhoea incidence among children under five years in Ghana. The study employed logistic regression model and used a nationwide dataset from the Demographic and Health Survey (DHS), 2008 with a sample size of 2,728 women who had given birth and found that household's type of place of residence, age of under five children as well as household's wealth status rather found to strong predictors of under five diarrhoea in Ghana. However, household's type of toilet facility and drinking water source were found not significant predictors of under five diarrhoea. Meanwhile, household water treatment proven to be significant in improving microbial quality of water and reducing diarrhoea was not considered in the analysis. Given this backdrop in literature the current study examined the effect of household water treatment on the incidence of under five children diarrhoea in Ghana.

Essilfie, Padi and Addor (2017) analysed the effect of water and sanitation on the occurrence of diarrhoea in the Ghanaian context using the 2011 Multiple Indicator Cluster Survey dataset. The study established that access to improved water and toilet facilities decreases under five diarrhoea among children, using Probit as the econometric analysis with a sample of 4925 households in Ghana. In contrast, Nketiah-Amponsah and Afful-Mensah (2017) recently, examined the relationship between the source of drinking water and the incidence of diarrhoea among children under five and it was found that drinking from improved water sources rather increases the odds of diarrhoea risk among under five children by about 1.3 times. However, the study did not consider the relative effective of household water treatment intervention in reducing diarrhoea diseases among under five children in Ghana.

Macdonald (2017), explored household water treatment and safety storage (HWTS) in Ghana as an interim solution and the arguments for scaling-up HWTS to meet the immediate needs of populations currently without safe water and established that HWTS is very effective as an interim solution of achieving a long-term access provision of safe to all, hence needs to be scaled up. However, the researcher did not consider the effectiveness of household water treatment as intervention on diarrhoea reduction. Given this backdrop in literature, the current study therefore, examined the effect of household water treatment of diarrhoea in Ghana.

Chapter Summary

The literature reviewed in this chapture suggest that intervention in water quality, particularly, household or point-of-use water treatment is effective in reducing diarrhoea among children under five. A large number of studies reviewed on water quality intervention focused on household water treatment practices using appropriate technologies and suggest that a greater impact on reduced diarrhoea illness among children under five. In Ghana, although some found improved water to be effective in reducing diarrhoea among children under five, majority had inconclusive results. However, most of the studies reviewed focused on improved water. This study adds to the body of reviewed in examining the effect of household water treatment on under five diarrhoea status. In particular, this study builds on studies in Ghana to cover improvement of water quality at the household level in reducing diarrhoea.

CHAPTER THREE

RESEARCH METHODS

Introduction

This chapter presents the methodological context within which the study is situated. It discusses the research design, the data source and description, theoretical model on which the study analysis is built, the empirical model used for testing the study hypotheses, the description of the variables employed in the model. This is followed by the estimation procedure and how the post-estimation tests of the study were conducted.

Research Design

This study employed a cross-sectional secondary data based on the positivist philosophy and quantitative approach. The positivist believe that reality is stable and can be observed and described from an objective viewpoint without inferring with phenomena being studied. This design was adopted for the study because the positivist is theoretically inductive and depends on quantifiable observations that lend themselves into statistical analysis to validate, reject or refine hypotheses. This means that results from the study are not obtain due to value judgement, but based on a scientific method of inquiry.

Data Source and Description

The study used a nationwide dataset from the Ghana Demographic and Health Survey (GDHS), 2014. This Ghana Demographic and Health Survey (GDHS survey provide a wide range indicator of population, health, including under five diarrhoea and nutrition. Given that the main focus of the study is to examine the effect WASH on child diarrhoea in Ghana, the most recent Ghana

Demographic Health Survey conducted in 2014 (i.e. sixth round, GDHS 6) was employed. The study uses information from this survey's document on diarrhoea status of Ghanaian children as an outcome (dependent) variable and demographic and housing characteristics as explanatory (explanatory) variables.

The household member and children recode files (datasets) were used for the analysis. The household member dataset has one record for each household. It concludes household member's roster and the background information on all members of the household. The unit of analysis in this file case is the household. On the other hand, the children files contain information on every child of eligible women, born in the last five years (0-59 months). These two files (household member and children recode files) are used to generate the three main explanatory (independent) variables, that is improved water, improved sanitation and household water treatment. The two files are used because the household member dataset has information on child health outcomes but lacks other child-related variables such as diarrhoea disease status size at birth and multiple birth. To capture the data needed for the child health outcome (diarrhoea) and characteristics, the household and children datasets were merged.

Sampling technique and the sample size

The Ghana Statistical Service (GSS) surveyed the Ghana Demographic Health Survey (GDHS) dataset based on multi-staged probability sampling technique using the 2010 Population and Housing Census (PHC) sampling frame. The first stage of the probability sampling involves the selection of enumeration areas (EAs) in the ten administrative regions and a total of 427

EAs were selected, 216 in urban areas and 211 in rural areas. The second stage of the probability sampling involved the systematic sampling of households and 30 households were selected from each EA to constitute a total sample size of 12,831 households. Overall, 11,835 household were successfully occupied and interviewed, in a response rate of 99 percent. The complete merge file for this study included a total of 5884 observations. However, following data cleaning on issues such as children whose households had missing values, non-reponse/not applicable and 'do not know', the weighted sample obtained for descriptive and full model regression on the health outcome was 5301Ghanaian children under five years.

Theoretical model

The study was based on the health production function (HPF) theoretical model first developed by Grossman (1972) and subsequently used by many other for their respective field. As mentioned previously, the study follows Grossman (1972) theory, Jacobson (2000) theory and Alberini *et al.* (1996) theory of illness and defensive to assess child under health status. As a result, under five diarrhoea status is used as an outcome (dependent) variable is cause by environmental factors such as water, sanitation and other important determinants.

$$Y^* = X' \beta + \varepsilon$$

Where, Y^* represents outcome or dependent variable, in this case diarrhoea among children under five years reported by the mother two weeks preceding the survey interview, β contains the parameters to be estimated, X' represents the independent variables used in the study and ε measured as the error term that follows a one-way error component model. Based on the review of previous studies (Essilfie, Padi & Addor, 2017; Allawala, Barry & Kayani, 2017) and also theoretical literature found to be relevant to this study as well as objectives of this study, the study adopts the model express as:

$$\text{ChildH}_{ij} = \beta_0 + \beta_1(\text{WSH}_{ij}) + \alpha(\text{X}_{ij}) + \varepsilon_{ij}$$

Where (ChildH_{ij}) epitomizes the child health outcome in the Health production function. In this study, the health outcome is a child under five diarrhoea measured during the period of two weeks preceding the survey for a child in household j. (WSH_{ij}) represent a vector of environmental factors such as households' water, sanitation and hygiene status, whereas the matrix (X_{ij}) includes all controls. The ε_{ij} captures the idiosyncratic errors.

Therefore, following the three (3) theoretical models adapted for this study, thus Grossman (1972) model, Jacobson (2000) model and Alberini *et al.* (1996) model, empirical studies and objectives of this study, the dependent variable is child under five diarrhoea whiles the following set of explanatory variable was used for the empirical model {water source, treatment of water, sanitation facility, child's stool disposal, households' wealth status, mother's age, mother's education level, child's sex, and age, multiple birthtype, type of place of residence and region}.

The Empirical Model

The choice of these variables was based on the objective of the study and theoretical considerations. Therefore, the empirical model for this study is represented as:

$$Chdiarr_i = \beta_0 + \beta_1 Impwat_i + \beta_2 Trewat_i + \beta_3 Imptoi_i + \; + \beta_4 Hwealth_i + \beta_5 Moage_i + \beta_6 Moeduc_i + \beta_7 Chsex_i + \beta_8 Chage_i + \beta_9 Birthtype_i + \beta_{10} Residence_i + \beta_{11} Region_i + \varepsilon_i$$

Where $Chdiarr$ = Child under five diarrhoea status; $Impwat$ = Main source of water; $Imptoi$ =Type of toilet facility; $Chstool$ = Safe disposal of child's stool; $Hwealth$ = Households wealth status; $Moage$ = Mother's age; $Moeduc$ = Mother's educational level; $Chsex$ = Child's sex; $Chage$ = Child's age (0-59 months); $Birthtype$ = Child's birth type; $Residence$ = Type of place of residence (rural/urban); $Region$ = Region of residence (the ten administrative regions)

Variables Description and Measurement

Dependent/Outcome Variable

Under Five Diarrhoea

As noted earlier, the outcome variable is diarrhoea among children under five defined as the passage of three or more "loose watery stools" in a 24-hour period. As captured in the DHS, in most of the cases, the respondents are the child's primary caretaker – usually their mother and were asked to answer to the question whether the child suffered from diarrhoea in the past two weeks preceding the interview. This question was asked to all mothers with living children under five years old. In terms of measurement, the variable is a binary response captured as dummy with the value of one (1), if the mother responded that yes child had diarrhoea and zero (0), otherwise. It's worth noting that, intuitively, the two-week period is to reduces possible recall bias that may arise. However, two-week period diarrhoea self-reported can have some bias. In addition, due to the subjective nature, reported diarrhoea status may be correlated with some other unobserved variables. For instance, the possibility of the mother reporting the child diarrhoea status could be affected by mother's education level, even though there is no empirical evidence to support this claim.

Independent Variables

Based on existing empirical literatures, a set of household environment factors such as improved water source, improved sanitation and Hygiene in terms of safe disposal of child's stool was considered. Also, household, health-seeking behaviour i.e. Treatment of water was incorporated to improve the water quality.

Water Source

One of the main variables of interest considered in this study was water as measured by improved source for drinking water available to the household. Several studies have tried to examine the association between water on child diarrhoea and have established that the type of water source used by households is expected to be negatively associated with incidence of child diarrhoea. In Ghana, access to improved water has a potential health benefits for households and children in particular. Reduction of children's exposure to water-borne diseases such as diarrhoea, guinea worm, typhoid, cholera and dysentery that are common in Ghana can be achieved when safe water is available and easily accessed by households.

The Ghana Demographic Health Survey (GDHS) capture 13 types of water sources for households: piped into a dwelling, piped into the yard / plot, public tap/standpipe, borehole, protected well, unprotected well, protected spring, river, rainwater, tanker truck, cart with small tank, bottled water, sachet water and other. With these sources, several studies have used different categories, for instance, Hong, Banta and Kamau (2007) used safe and unsafe while Annim and Imai (2014) used piped and not piped. However, such simple categorizations is believed to miss the nuances in terms of differences of households access water sources in Ghana as captured in the WHO and UNICEF Joint Motoring Program (JMP). Therefore, based on WHO and UNICEF (2017) to know whether it was improved or unimproved, the variable was dichotomized into two main categories labelled as improved (1) and non-improved (0) as presented in Table 2.

Sanitation Facilities

Sanitation here was assessed in terms of the type of toilet facility used by the households. The question on toilet facility was to find out the type of toilet facility used by mothers and as to whether it was improved or unimproved. As a result, 11 types of toilet facilities were also identified where the responses that were provided for mothers to choose from ranged from flush to the piped sewer system, flush to septic tank, flush to pit latrine, flush somewhere else, flush don’t know where, ventilated improved pit latrine, pit latrine with slab, pit latrine without slab, no facility/bush, composting toilet, bucket/pan and other. Accordingly, following the WHO/UNICEF (2017) definition and classification of sanitation facilities, this was recoded into two as improved (1) and unimproved toilet facility (0) as presented in table 2.

Table 2: classification of water and sanitation by the WHO/UNICEF Joint Monitoring Program (JMP) for water and sanitation

WATER	
'Improved' sources of water	***'Unimproved' sources of water***
Piped water, boreholes or tube wells, protected dug wells, protected springs, rainwater, and packaged delivered water.	Unprotected dug well, unprotected Spring, river, dam, lake, pond, stream, canal and irrigation canal
SANITATION	
'Improved' sanitation facilities	***'Unimproved' sanitation facilities***
Flush/pour flush to piped sewer systems, Septic tanks or pit latrines; ventilated improved pit latrines, composting toilets or Pit latrines with slabs.	Pit latrines without a slab or platform, hanging latrines or bucket latrines and open defecation.

Source: WHO/UNICEF (2017).

Household Water Treatment

One main factor that puts much burden on child's health in Ghana is lack of access safe drinking water. Despite the remarkable progress in 'improved' water coverage, access to safe or clean water at the household level is still an issue of concern due to water contamination. This has resulted in many deaths of children, particularly, children under five in the developing countries, including Ghana. As a recent study revealed that improved water rather increases the odds of diarrhoea diseases among Ghanaian children under five by 1.3 times (Nketiah-Amponsah & Afful-Mensah, 2017). Household water treatment has been widely advocated as a means of decreasing the burden of diarrhoea diseases among young children in areas where access to safe water is an issue. As a result, this study sought to find out the various ways through which mothers treat water at the household level to make their water safe for drinking. The DHS, the responses were categorized into boiling, bleach or chlorination, strain through a cloth and water filtration. Household water treatment was recoded into two categories, thus households that treats as yes (1) and no (0) for otherwise. It is expected that treated or yes (1) will lead to health gains in terms of diarrhoea reduction.

Control variables

These factors affect the dependent variable directly, but are not the main variable of interest so they are control for. These control variables include the mother and child's household socio-economic and environmental characteristics.

Wealth Status

The phenomenon is generally attributed to the standards of living in terms households' levels of income, especially, in the developing countries, including Ghana, where diarrhoea is prevalent among children, This implies that si significant higher wealth category household are manifested in childhood diarrhoea reduction since these household are able to access appropriate health facilities to produce good health for their children compared to households within the lower category. The variable was considered in this study since it provides a consistent measure of combined indicators of household income and expenditure information on the wealth status of Ghanaian households. In the DHS, the question usually asked is whether the household has a number of suggested items ranging from television set to bicycle or car as well as household characteristics. These responses were grouped into five categories poorest, poorer, middle, richer and richest. It is expected that there will be a decreasing risk of diarrhoea among children under five the household wealth status increases: poorest (1), richest (5).

Mother's Age

Literature suggests that, the health of a child essentially depends on the health of the mother and the maternal age at birth. The age of the mother at birth, in any case, suggests how best she can be of help to the vulnerable child. According to Nkansah (2014), mothers whose age are usually less than 20 years are considered to be more vulnerable to some sort of stress that comes with pregnancy and childbirth and likely not to properly take care of themselves and protect their children from some preventable diseases such as diarrhoea. In the DHS, this variable was captured as a continuous variable, ranging from 15-49 years covering childbearing age. Hence, it is expected that as mothers age increases, there will be a decreasing probability of morbidity due to diarrhoea among children under five.

Mother's Education

Of all the factors associated with satisfactory diarrhoea, the role of the mother is of key importance. It has been reported that maternal education, is a major determinant in achieving better child health in both developed and lower/middle income countries. The influence of maternal education on child health is largely established globally. In Ghana, a study by Agyemang (2013) indicates that the highest level of education mother attains significantly reduce the risk of diarrhoea among children under five years. The rationale behind this is that educated mothers are better informed of the health hazards of most prevailing conditions such as unsafe water or unimproved sanitation facilities and its repercussions, hence, in a better position to protect the child from diseases that are associated with such conditions.

The DHS classifies this variable into "no education", "primary education", middle/JSS and "secondary or higher. As noted, mothers with middle/JSS and secondary or higher education are more likely to be knowledgeable about such diseases and are expected to be able to protect their children from such diseases. Also, mothers with primary education may be privy to some behavioral practices required to protect their children from such preventable diseases. In contrast, mothers with no education may not have the required knowledge of the inherent diseases associated with inadequate sanitation facilities and therefore will be less capable of protecting their children from such diseases. Therefore, following this the study it is expected that the likelihood of under-five morbidity and mortality due to diarrhoea will decline as maternal education rises.

Sex of the Child

The sex of a child has implications for children's health. According to Singh, Bloom and Brodish (2015), there is increasing recognition in the field of international health that gender inequities and dynamics are a major social determinant of health outcomes among children. Household decision-making and attitudes toward gender-based are associated with child health outcomes in Africa. Generally, it is assumed that in the absence of gender-based discrimination in the care and treatment of young children, female children are expected to have better health gains than males. This is due to the fact that the biological factors of females tend to favour them than male who are usually expose to the environment, especially in early infancy. The sex of the child is captured by a dummy variable equal to 0 for male child and 1 for a female child. The sex of the child is controlled for to examine to identify either it is the male or female that suffer most from the potential risk of diarrhoea.

Age of the Child

This study is interested in children under five years and only age in months from zero to fifty-nine (0-59) or in completing years captured as 0, 1, 2, 3 and 4 were considered. The age of the child under five is reported to significantly affect morbidity and mortality due to diarrhoea. Older children are believed to be less susceptible to diarrhoea disease compared to younger ones. As a result, it is expected that the child's age will be inversely related to under-5 morbidity and mortality due to diarrhoea.

Multiple Birthtype

Health economists have suggested numerous passageways through which multiple birthtype affects child well-being. Generally, single child is believed to be less susceptible to diarrhoea disease compared to multiple or twin birthtype. As a result, this variable was dichotomised into single (0) and twin (1). As mentioned, it is expected that the child's birthtype will be positively related to under five morbidity and mortality due to diarrhoea as the child's birth type increases in terms of numbers.

Place of Residence

Given the disparities in distribution of social infrastructures within the rural-urban areas, it implies that the type of residence in which the child is born and raised is deemed to greatly affects the health status. In Ghana the rural areas are deprived in terms of infrastructure than what pertains in urban areas, hence there are great disparities between rural and urban households and limited access to social amenities, they live in insanitary environments which predispose them to various kinds of diseases, including diarrhoea. On the other hand, it should be noted that rural communities may have lower population densities which may be more comfortable with less pressure and cleaner environment, but few health facilities and other social infrastructure that will allow for the production of good health. In the DHS, this variable is a dummy, thus rural (0) and urban (1).

Regions of Residence

The variable for the ten administrative regions in Ghana explains the regional difference in which each child was born. This was controlled to established the disparities since some regions are endowed with economic and social factors that favour good health while others are not and this can significantly affect child health. That is the possibility that mortality rate would be low in Grater Accra region compared others is high since Greater Accra regions that are highly endowed with economic and social factors that favour good health than others. Similarly, among the three northern regions, mortality rate due to diarrhoea are expected to be high.

Table 3: Definition, measurement of variables and A' priori Sign

Variable	Type	Definition	A' priori Sign
Under-5 diarrhoea	Dummy	Has the child had diarrhoea	Dependent variable
Water source	Dummy	Improved water	Negative
Treated water	Dummy	Treatment of water	Negative
Sanitation facility	Dummy	Improved toilet	Negative
Wealth index	Categorical	Wealth quintile	Negative
Mother's age	Continuous	Mother's age in years	Negative
Mother's education	Categorical	Mother's education level	Negative
Child's sex	Dummy	Gender of the child	Indeterminate
Birth type	Dummy	The birth type of the child	Indeterminate
Child age	Continuous	Child age in months (0-59)	Negative
Residence	Dummy	Type of place of residence	Indeterminate
Regions	Categorical	The ten regions	Indeterminate

Source: Author's own construct adapted from literature, 2019.

Estimation Techniques

Given the nature of the data used in this study as cross-sectional, univariate analysis was used to describe the prevalence of diarrhoea among child under five. In addition, the bivariate analysis, using cross tabulations, and Chi-square tests as well as Cramer's V test were adopted to discern the association between the independent variables and the dependent variable. Also, with regards to the multivariate regression, the study adopted a probit model to test the hypotheses of the objectives outlined in this study as well as to ascertain the effect of independent variables on the dependent variable.

The Probit Model.

The probit model is applied in the estimation of binary models with the use of Cumulative Distribution Function (CDF). In order to arrive at the probit model, an unobservable index is used and one or more of the explanatory variables determine this unobservable index. The higher the unobservable index, the higher the chances of obtaining success defined as the dependent variable and denoted as 1. Therefore, given dependent variable as a binary/dummy response, which takes a value of one (1) or zero (0) depending on whether or not a child had diarrhoea or not (i.e. Had diarrhoea=1 and no diarrhoea=0), the probit model using the Maximum Likelihood Estimation (MLE) technique was adopted for this study. The method of maximum likelihood consists of estimating the unknown parameters in such a manner that the probability of observing the dependent variable is as high (maximum) as possible (Gujarati, 2006).

Also, according to Pindyck and Rubinfield (1991), maximum likelihood estimation yields some consistent parameter estimators. Thus, the

MLE produced maximum likelihood values for the parameters given the sample data.

$$L(\beta/y)\prod_{i=1}^{n}[\phi(X'\beta)]^{yi}[1-\phi(X'\beta)]^{1-yi}$$

Where β is vector of predictors. The log Likelihood function is then written as:

$$nL\left(\frac{\beta}{y}\right)=\sum_{i=1}^{n}\{y_i\,In\phi(X'\beta)+(1-y_i)In[1-\phi(X'\beta)]\}.$$

Generally, the probit model allows for estimating the probability that an event occurs or not, by predicting the dependent outcome of a set of independent variables. Consequently, it has advantages compared to the linear probability model (LPM) since it guarantees that the estimated probabilities fall between the logical limits zero (0) and one (1). In addition, it ensures that the relationship between P_i *and* X_i is nonlinear (Gujarati, 2006). Systematically, the probit model is specified as:

$$Y^*=X'\,\beta+\epsilon$$

$$Y^*=\begin{cases}y=1, & \text{if } y^*>0\\ y=0, & \text{if } y^*\le 0\end{cases}$$

$$Pr(Y=1|X_i)=Pr(X_i'\,\beta+\epsilon>0|x)$$

$$Pr(Y=1|X_i)=Pr(\varepsilon_i>-X_i'\,\beta)$$

Assuming that the error terms are independent and normally distributed with zero mean and unit variance. Equation changes to probit model

$$Pr(Y_i=1|x)=1-\phi\left(-\frac{x\beta}{\sigma}\right),\sigma=1$$

$$Pr(Y_i=1|x)=1-\phi\left(X_i'\,\beta\right)$$

Where ϕ (.) represents the standard normal distribution and the X_i is a matrix that represents determinants of diarrhoea among children under years. Therefore, without loss of generality, the functional form of the linear probability model is specified as follows (Gujarati, 2006).

$$P_i = \Pr(Y = 1|X_i) = \phi(\beta_1 + \beta_2 X_i) = P(Z_i \leq (\beta_1 + \beta_2 X_i)$$

Where the expression $P_i = \Pr(Y = 1|X_i)$ means the probability that an event occurs given the values of the X, or explanatory variables and where Z_i is the standard normal distribution function which is $Z_i \sim N(0, \sigma^2)$. F is the standard normal from the cumulative distribution function which is written explicitly in the present context as:

$$F = \frac{1}{\sqrt{2n}} \int_{-\infty}^{Y} e^{-Z^2} dz = \frac{1}{\sqrt{2n}} \int_{-\infty}^{(\beta_1 + \beta_2 X_i)} e^{-Z^2} dz$$

Where P_i represents the probability that a child in the household will have diarrhoea or not. This equation is known as the cumulative logistic distribution function and Z_i ranges from $-\infty$ to $+\infty$; P_i also ranges between 0 and 1; P_i is also non-linear related to Z_i (that is X_i) thus, satisfying the two conditions required for a probability model. In satisfying these requirements, an estimation problem has been created because P_i is non-linear not only in X but also in β's. This means that one cannot use ordinary least squares procedure to estimate the parameters (Gujarati, 2006).

Justification of the estimation technique

The dependent variable was a binary response which takes on the value of 1 if a child was reported to have diarrhoea and 0 being otherwise. This explains that both probit and logit can be used to analyse the study. However, the study adopted the probit model over the logit model. Although the logit model is extremely attractive because of its computational simplicity, it is burdened with a property termed as the 'independence of irrelevant alter-natives" that is quite unrealistic in many choice situations, as Hausman and Wise (1978) clearly noted. The probit model on the other hand, allows for a much richer range of human behavior than does the logit model (Hausman & Wise, 1978). An important characteristic of the probit model is its provision for correlation among the random components of utility and, as a by-product, the explicit allowance for variation in tastes across individuals for the attributes of alternatives (Hausman & Wise (1978).

The Endogenous Treatment Effects Model

To assess the effect of household water treatment of diarrhoea, an important methodological issue that has to be acknowledged is that treatment of water may be endogenous (Tan & Capuno, 2012). Because, an unobserved heterogeneous factor can influence the household's decision to treat water before drinking at the household level. Therefore, using the conventional probit only, for the estimation, may be biased and may not reflect the true estimated effect of water treatment status on diarrhoea due to reverse causality (simultaneity bias), omitted variables bias or measurement errors. Therefore, to address potential endogeneity issues, the study employed the endogenous treatment effects model with a binary outcome, as introduced by Heckman, (1976, 1978) and Maddala (1983) in the Structural Equation Model (SEM) frame, to accommodates endogenous selection issue.

Here, the outcome of undertaking the treatment (i.e., treating water) is explained by a binary discrete variable expressed through diarrhoea. To account for potential endogeneity, the endogenous treatment effects model with a binary outcome using a latent factor framework and estimate the parameters using the Maximum Likelihood Estimator (MLE). Under this approach, the outcome of undertaking the treatment (i.e., Treating water) is explained by a binary discrete outcome described in diarrhoea status. The outcome equation, as expressed by child diarrhoea, includes household main water source, sanitation and a vector of explanatory variables depicting respondents' socio-demographic characteristics. Therefore, it can be express as"

$$Y_J^* = \delta T_J + X_J \beta_1 + \varepsilon_J$$

Where endogenous treatment-regression model is formally composed of an equation for the outcome Y_J^* representing whether there is a presence of diarrhoea. The covariates X_J are unrelated to the error terms; in other words, they are exogenous. T_J attempts to produce an estimate of δ, the impact of the treatment (i.e., the decision to treat water or not). It seems inevitable, however, that some unobserved determinants would also determine the decision to treat water or not. If so, then the least squares estimator of δ will inappropriately attribute the effect of the treatment, rather than to these underlying factors. Therefore, the decision to obtain the treatment is made according to the rule:

$$T_J^* = Z_J \theta + u_J$$

Also, to address concerns about omitted variable bias and reverse causality, exogenous variables, Z_J is included in the treatment equation. In particular, Z_J is a vector of the indicators used in the analysis to describe factors that influence household's decision to treat water prior to drinking such as individual's educational attainment.

$$T_J^* = \begin{cases} 1 & \text{if } Z_J\theta + u_J > 0 \\ 0 & \text{if otherwise} \end{cases}$$

Where T_J is a binary-treatment variable that is assumed to stem from an unobservable latent variable indicating the household's decision to treat drinking water, taking the value of 1 for treating water and 0 for non-treated. The error terms ε_J and u_J are assumed to be bivariate normal with zero mean.

$$\begin{bmatrix} \sigma^2 & \rho\sigma \\ \rho\sigma & 1 \end{bmatrix}.$$

Interpretation of results

Unlike the linear regression models, in probit, the mean and variance of the dependent variable are not separately identified. This is because probit model regression coefficients are always attenuated (they are lower bounds to the true or underlying coefficients unless all relevant covariates are included), as a result, it is difficult to interpret their magnitude in substantive terms. Unlike the linear models, where the slope coefficients represent the marginal effects of the explanatory variables on the dependent variable. As Gujarati (2006) clearly noted, non-linear models like probit model coefficients have no direct interpretation. As such, we generated the marginal treatment effects (MTE) estimated expressed as the average marginal effects to measure the effect of the explanatory variables on the dependent variable.

Average marginal effects (AME) measure the average percentage change in the probability of reporting success in the outcome. In the context of this study, the average marginal effects measure the average percentage change in the probability of reporting diarrhoea. Furthermore, in order to provide a deeper insight into the influence of household water treatment on child diarrhoea, the marginal treatment effects (MTE) are estimated. The MTE are expressed as the average effect of treating water on diarrhoea for individuals who are on the margin of indifference between having decided to treat or not.

Post- Diagnostics Tests

The following diagnostics and post estimation, tests were also conducted to ensure that the estimates from the regressions are robust, unbiased and consistent, the data was first observed to deal with influential observations, outliers, missing values and implausible values.

Model Specification Test

Empirical research is usually an interactive process begins with a specification of the relationship to be estimated. Selecting a specification usually involves several choices: the variables to be included, functional form connecting these variables, and the dynamic structure of the relationship between the variables. This involves two aspects, when dealing with the regression equation. First, consider the link function of the outcome variable on the left-hand side of the equation. The assumption here is that the regression equation is the correct function to use. Secondly, on the right-hand side of the equation, the assumption is that all the relevant variables are included, and that the model does not include variables that should not be in it, and that the regression equation is a linear combination of the predictors.

For example, it could happen that the probit function as the link is not the correct choice or the relationship between the probit of the outcome variable and the independent variable is not linear. In such case, we have specification error. This misspecification of the link function of probit model is usually not too severe, compared with using other alternative link function choices such as logit. In applied, there is more concern with whether a model has all the relevant predictors and if the linear combination of the predictors is sufficient.

There are several methods to detect specification errors. The Linktest performs a model specification test for single-equation models. The Stata command Linktest can be used to detect a specification error, and it is issued after the logit or logistic command. The idea behind Linktest is that if the model is correctly specified, one should not be able to find any additional predictors that are statistically significant except by chance. After the regression command (in this case, logit or logistic), Linktest uses the linear predicted value (_hat) and linear predicted value squared (_hatsq) as the predictors to rebuild the model. The variable _hat should be a statistically significant predictor, since it is the predicted value from the model. However, in the case of testing for omitted variables(s), emphasis is placed on the _hatsq and it is not supposed to be significant. This is what is used in this study do to the model specification test. This will be the case unless the model is completely misspecified. On the other hand, if our model is properly specified, variable _hatsq should not have much predictive power except by chance. Therefore, if _hatsq is significant, then the Linktest is significant. This usually means that either we have omitted relevant variable(s) or the link function is not correctly specified.

Multicollinearity Test

Multicollinearity refers to a situation whereby there is a high correlation among the explanatory variables. In other words, collinearity for short occurs when two or more independent variables in the model are approximately determined by a linear combination of other independent variables in the model. The degree of Multicollinearity can vary and can have different effects on the model and if the degree of correlation between variables is high enough, it can cause problems when the model is not fitted since, it indicates that changes in one variable are associated with shifts in another variable. A Multicollinearity is a potential problem because, the estimate will be very sensitive to changes in specification. This is a consequence from the fact that there is very little unique variation left to explain the dependent variable.

As a result, he parameter estimate becomes unstable and sometimes even result in wrong signs for the regression coefficient, despite the fact that it is unbiased. A wrong sign is referred to a sign that is unexpected according to the underlying theoretical model, or the prior believes based on common sense, (Wooldridge, 2010). Fortunately, there are several simple tests in the statistical software to gauge multicollinearity in a regression model. For instance, the variance inflation factor (VIF) identifies correlation between independent variables and the strength of that correlation. A rule of thumb, a variable whose VIF values are greater than 10 may merit further investigation. Also, tolerance, defined as 1/VIF, was also used to check on the degree of collinearity. A tolerance value that is lower than 0.1 is comparable to a VIF of 10. It means that the variable could be considered as a linear combination of other independent variables.

Chapter Summary

The objective of this chapter was to explain in detail the research methods used to analyse the data required for this study. The research design was first described where the positivist approach to research was adopted. This was followed by the data type and source. Empirical models encompassing all the variables (dependent, independent and control) were specified. A Probit model technique was employed and a post estimation test specification was stated. Also, a detailed description of Endogenous Treatment Effect estimator, a technique that helped in controlling for the possible endogeneity.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

The chapter presents the results of the study and discusses their implications with respect to the literature. The chapter is divided into two with It first covering the descriptive analysis (univariate and bivariate) while the second touches on the multivariate analysis (regression analysis). The findings are presented in the form of tables and graphs (figures), showing the relationship between water, sanitation, household water treatment and childhood diarrhoea in Ghana. The analysis is based on the 2014 round of the Ghana Demographic and Health Survey dataset which provides information on the situation of children and women and measures key indicators that allow countries to monitor progress towards the Sustainable Development Goals (SDGs).

Descriptive Statistics

Table 4 presents a brief descriptive statistic of the dataset used in this study. Out of the total sample of 5301 used for the study, the mean age for children and mothers were recorded to be 28 months and 31 years respectively.

Also, the data suggest that on average, children spend 21 minutes to get access to a water source, with a minimum of zero (indicating having water pipe borne household) and a maximum of 180 minutes respectively. In the same, the data indicated that the average time spent by children in households to travel to a sanitation facility such as toilet is around 19 minutes, with a minimum of one (indicating having a toilet facility on the premises) and maximum of 120 minutes respectively.

Table 4: Descriptive Statistics of Continuous variables

Variables	Mean	Std. Dev.	Minimum	Maximum
Child Age	27.885	17.163	0	59
Mother's Age	30.674	6.872	15	49
Time to access water	20.564	20.819	0	180
Time to access toilet	19.409	12.081	1	120

Source: Author's computation from the GSS *et al.* (2019).

Univariate Analysis

Prevalence of diarrhoea among children under five

Figure 5 shows the prevalence of diarrhoea among children under five. The results proved to the fact that 12 percent of Ghanaian under five from the sample were reported to have been affected by diarrhoea bouts two weeks before the survey in 2014. This result is in line with the percent of children (12 percent) reported to be infected by diarrhoea in the entire datasets, of which 62 percent were treated with ORT or increased fluid. In addition, the result conforms to the recent study by Essilfie, Padi and Addor, (2017) that established that severe diarrhoea leading to dehydration is a major cause of the morbidity and mortality among under five children in Ghana. This explains that under five diarrhoea still persist in Ghana, despite it has declined compared to the previous years of 20 percent in 2008.

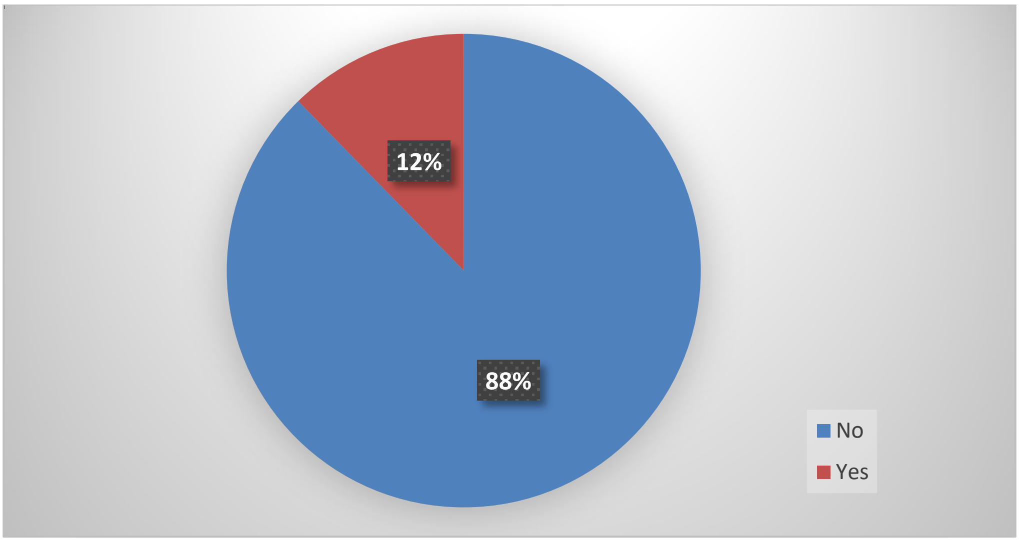


Figure 5: Current rate of under five diarrhoea in Ghana

Source: Author's computation from the GSS *et al.* (2019).

Sources of households drinking water in Ghana

Availability of drinking water has been advocated as a means of decreasing the burden of diarrhoea diseases among young children. The type of water source indicates whether availability of water is suitable or healthy (quality) for drinking. Lack of ready access to suitable or healthy water source may limit the quality of water that is available to the household. Figure 6 shows the percentage distribution of source of drinking water among Ghanaian households. As shown, out of the total sample, a greater part (45 percent) of Ghanaian are living in households that use water supplied from well or boreholes. This is followed by pipe water (28 percent), and bottle or sachet water (14 percent). Surface water is the least used source of drinking water among children under five representing 12 percent. This confirms the significant progress made by Ghana in providing access to water sources to more than 80 percent of the population (UNICEF/WHO/World Bank, 2015).

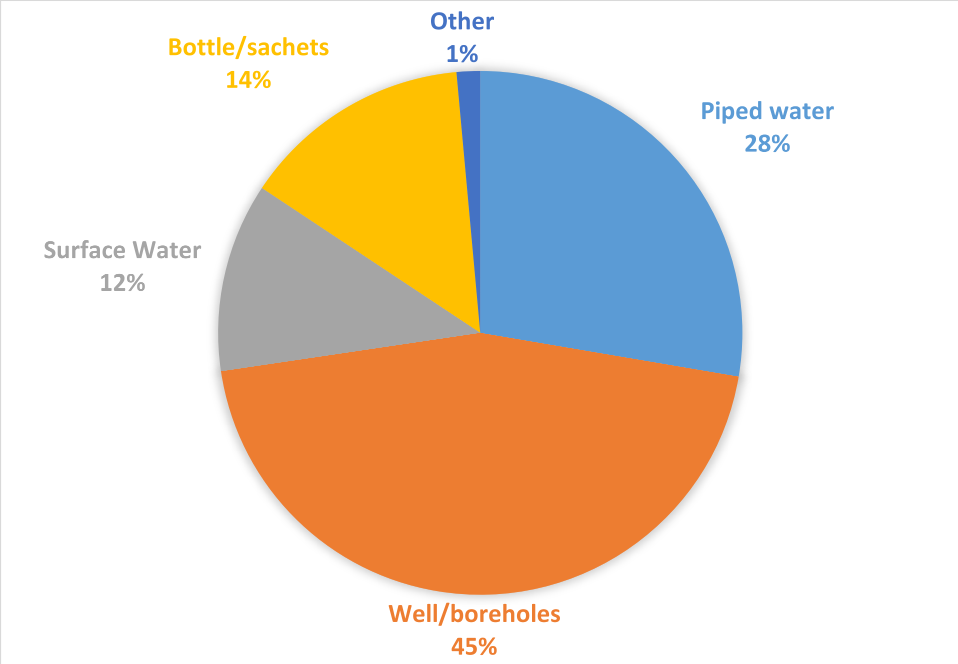
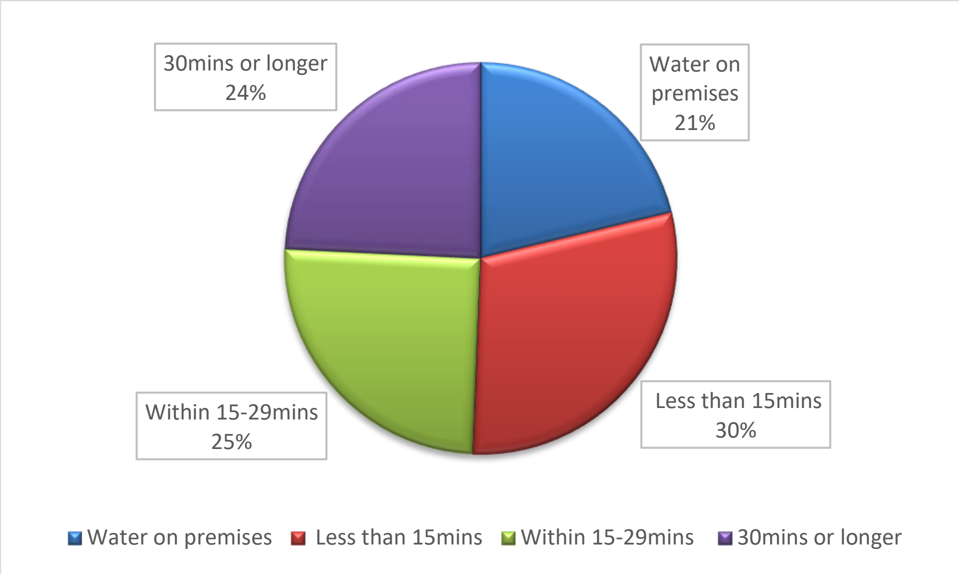


Figure 6: Sources of household drinking water in Ghana

Source: Author's computation from the GSS *et al.* (2019).

Time spent to get to water sources

Despite the massive commitment by policy makers and stakeholders to increase the supply of water to households, many households have a deficiency in daily quantity and quality of water required for drinking and for general use due to longer distance travel to get access to water. Diarrhoea is a common problem among households that travel long-distance to access water source, since the possibility of water contamination is high during transportation. Figure 7 displays the percentage distribution of time spent by Ghanaian households to access water source. The results indicate that 30 percent of households spent about 15 minutes in order to get access to their water. This is followed by 25 percent (15 to 29 minutes), 24 percent (more than 30 minutes). Water on premises is the least in Ghana, recording 21 percent. This confirms the fact that many Ghanaian households travel long distances to fetch water from community pipes for domestic use (Akpalu, 2012).



.

Figure 7**:** Time spent by households to get to water source

Source: Author's computation from the GSS *et al.* (2019).

Methods of Household water treatment

To overcome the difficulties in providing safe water, point-of-use water treatment has been advocated as a means to improve access to potable water and decrease the global burden of diarrheal diseases. It is one of the most efficient interventions, which is highly cost-effective that households experiencing problems with water quality can adopt various methods for water purification. Figure 8 provides results on water treatment methods adopted by households in Ghana. Generally, most Ghanaian households (93.24 percent) do not treat their drinking water. In households where drinking water is treated, the majority of households use cloth to strain their drinking water (2.37 percent). This is followed household that treats their drinking water by boiling it (1.55 percent), allow to 'stand and settle' as well as camphor (0.85 percent). The least methods that are adopted by households in treating their drinking water are purification (0.56 percent), filtration (0.48 percent), and other (0.07 percent) respectively. The result is in line with the entire dataset of the Ghana Demographic Health Survey (GDHS, 2014) that the results, uptake and use is low among Ghanaian household that treats water is low (6.76 percent) and also difficult to identify the population that benefit most from the potential effect of the household water treatment intervention.

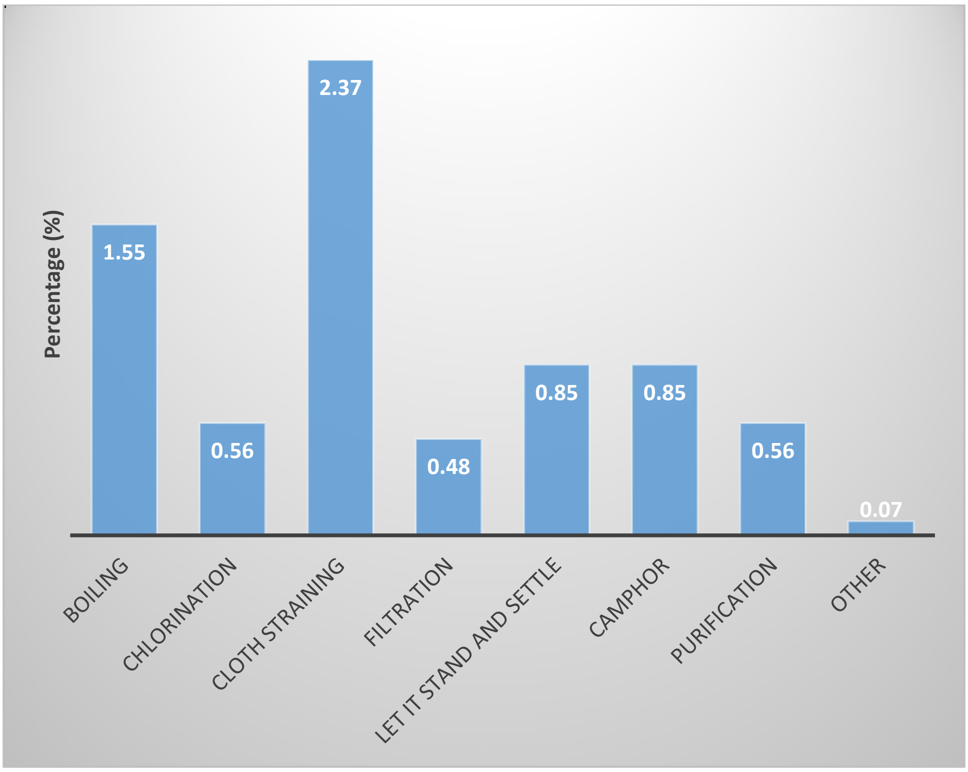


Figure 8**:** Methods of household water treatment in Ghana.

Source: Author's computation from the GSS *et al.* (2019).

Type of household sanitation facilities in Ghana

Figure 9 presents the types of sanitation facilities used in Ghanaian households. Several studies have highlighted the importance of the type of sanitation facilities on child health. A number of researchers have turned their attention to linking sanitation coverage to child health. According to Mbonye (2004), household without sanitation facility is 40 percent more prone to the risk of childhood diseases or poor health. From the figure 6, only 13 percent children live in households that have access to improved sanitation facility such as flush toilet (i.e. not shared), while 33 percent of children live in household without a toilet facility, implying that they used bush or open field for defecation. The results are in line with the Ghana Demographic Health Survey (GDHS) reported findings. According to the report, only 14 percent of households in Ghana have an improved toilet that is not shared with others. This also confirms the findings of Mariwah (2018) that the improvement in sanitation provision lags far behind that of water.

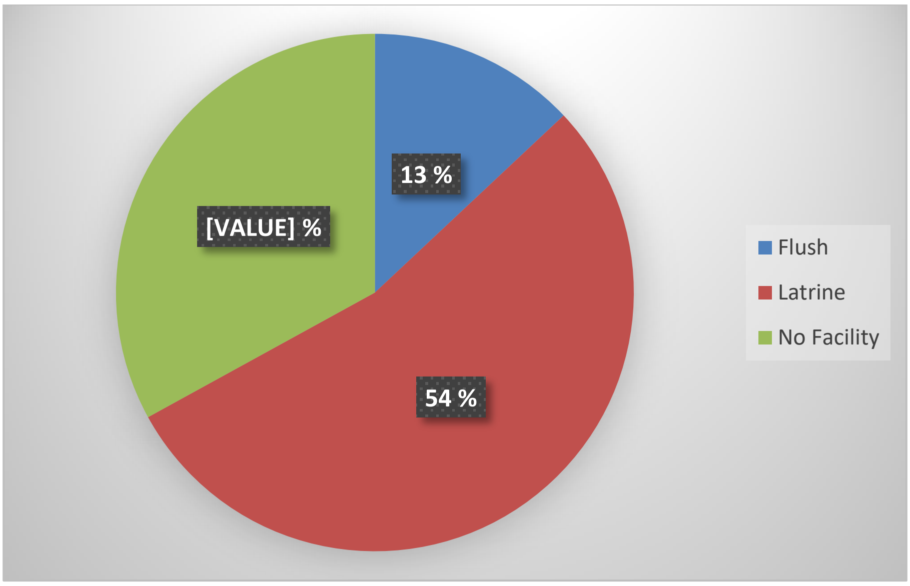


Figure 9: Types of household sanitation facilities in Ghana

Source: Author's computation from the GSS *et al.* (2019).

Mother's Educational level

Education is one social factor widely known to have a large and persistent impact on child health. Table 5 presents the distribution of mother's educational level. The results indicate that the majority of mothers sampled have formal education. This result is in compliance with the entire dataset Ghana Demographic Health Survey (GDHS) report, which states that, sixtyseven percent of women within ages of 15-49 are literate with at least secondary education.

Table 5: Distribution of mother's educational level in Ghana.

Mother's education	Frequency	Percent
No education	1850	34.90
Primary education	1092	20.60
Secondary education	2158	40.71
Higher/Tertiary	201	3.79
Total	5301	100

Source: Author's computation from the GSS *et al.* (2019).

Bivariate Analysis

In this section, bivariate analysis is analyse using cross tabulations, Pearson chi-square, and Cramer's V tests to assess the associations between key explanatory variables. The Pearson chi square is used to established the significance of the association among the variables, while the Cramer's V indicates the magnitude or extent of the association between the variables.

Association between socio-demographic characteristics and diarrhoea

Table 6 shows the bivariate analysis of the relationship between under five diarrhoea and background characteristics. It examines the extent to which child health outcome (diarrhoea) vary by children, mothers and household characteristics. The Pearson's Chi square test was used to discern the significance of the association between the variable in question and diarrhoea whereas the Cramer's explains the magnitude or extent in terms of the effect of the association. Using the Peason's Chi square test, the results showed significant association between most of the household characteristics and childhood diarrhoea. Child characteristics that were significantly associated with diarrhoea includes; age of child, and sex of the sex. The prevalence of diarrhoea was found to higher (20.14 percent) among children in the 18-23 months age group. Also, the results indicated that male children have a higher proportion of diarrhoea compared to girls, who coped slightly the risks of diarrhoea. As studies (Hong & Ruiz-Beltran, 2007; Essilfie, Padi & Addor, 2017) have shown, children in this group are the most vulnerable because in most cases they have just been weaned from breast-milk but have not quite yet adjusted to the intake of solid food. Although, the child birthtype (multiple birth) was not significantly associated with childhood diarrhoea, the prevalence of diarrhoea was higher (15.72 percent) among children who are twins compared to children born of single birth. This result confirms the evidence from the literature suggest that the number of young and older children in a household can have an effect on child health (Essilfie, Padi & Addor, 2017; Fenta, 2019).

Table 6: Prevalence of diarrhoea by socio-demographic Characteristics

Characteristics	Diarrhoea Prevalence	
	No (%)	Yes (%)
Child's sex		
Male	86.02	13.98
Female	89.5	10.48

Chi2 =15.3257 (0.000), Cramer's V = -0.0533

Child's age in month		
<6	95.47	4.53
6-8	87.66	12.34
9-11	84.89	15.11
12-17	82.35	17.65
18-23	79.86	20.14
24-35	82.74	17.26
36-47	92.76	7.24
48-59	92.87	7.13

Chi2 = 82.3210 (0.000), Cramer's V = 0.1720

Table Cont'D

Child's birth type		
Single	87.85	12.15
Twin	84.28	15.72
Chi2=2.5840 (0.108), Cramer's V = -0.0219		
Mother's age		
<20	80.63	19.37
20-34	87.88	12.12
35-49	88.11	11.89
Chi2= 9.2169 (0.010), Cramer's V = 0.0413		
Mother's education		
No education	86.17	13.83
Primary	87.43	12.57
Secondary	88.55	11.45
Tertiary	94.09	5.91
Chi2(3) = 13.3099 (0.004), Cramer's V = 0.0496		
Time to water source		
On premises	90.00	10.00
<15 minutes	88.37	11.63
15-29 minutes	86.80	13.20
>30 minutes	86.22	13.78
Chi2= 9.8951 (0.019), Cramer's V = 0.0433		
Quality of water		
Unimproved	90.19	9.81
Improved	86.61	13. 69
Chi2= 18.11148 (0.000), Cramer's V = 0.0501		
Quality of sanitation		
Unimproved	86.92	13.08
Improved	92.92	7.08
Chi2= 20.0795 (0.000), Cramer's V = -0.0615		
Treats water		
No	87.84	12.16
Yes	85.42	14.58
Chi2=1.7112 (0.191), Cramer's V =0.0178		
Residence		
Urban	88.01	11.99
Rural	87.48	12.52
Chi2= 0.3346 (0.563), Cramer's V = 0.0079		

Source: Author's computation from the GSS *et al.* (2019).

There are also significant association between under five diarrhoea and quality of drinking water used in the household as well as type of toilet facility used in the household. As presented in Table 6 above, the prevalence of diarrhoea was higher (13.69 percent) among children with poor access to improved water source. This implies that access to improved water rather increases the risk of diarrhoea and do not enhances child health. This finding is consistent with several studies (Bain *et al*., 2014; Nketiah-Amponsah & Afful-Mensah, 2017; Shaheed *et al*., 2014), who have argued that improved water sources indicators has been overemphasize, disregarding the fact that many continue to be contaminated and puts much burden on child health. With regards to the quality of, about twice the proportion of children (13.08 percent) living household without improved basic sanitation facility reportedly suffered diarrhoea compared with 7.08 percent living in household with improved sanitation facility such as flush toilet. The results collaborate with the findings of Annim and Imai (2014) as well as Essilfie, Padi and Addor (2017). According these studies, children living in households with improved flush toilet have better health gains than children living in households with other type of toilet facilities which are not improved.

Table 6 shows that that the prevalence of diarrhoea among children under five decreases as mother's age increases. The results indicate that the higher proportion of children whose mother's age is less than 20 years experienced higher (19.37 percent) of diarrhoea. Similarly, diarrhoea among children under five decreases as mother's educational level increases. Diarrhoea prevalence was high (13.83 percent) for mothers with no schooling, and low (5.91 percent) for mothers with higher education. This result validates and consistent with studies who have reported that child diarrhoea may vary by the educational level of female members of the household (Agyemang, 2013; Keats, 2018; Kier & Dai, 2018; Tampah-Naah, 2019).

Table 6 shows that the prevalence of diarrhoea among children under five years is lower in the urban areas compared to the rural areas, even though the Chi-square test of independence shows that the relationship between diarrhoea and place of residence is not significant. The results indicate that the prevalence of diarrhoea was higher (12.52 percent) among children living at the rural areas compared to the children living in the urban areas (11.99 percent). The result confirms the findings of a recent study that rural children are much exposed to have higher burden of a childhood morbidity (diarrhoea, ARI, anaemia, and fever) compared to their urban counterparts (Tampah-Naah, Osman & Kumi-Kyereme, 2019). This may be due to the difference in mother's education, availability of water and sanitary facilities, socio-economic status, access and utilisation of antenatal and delivery care.

Prevalence of diarrhoea by regional variations

Table 7 shows the results of association of diarrhoea prevalence among children under five and the region of residence in Ghana. The Chi-square test of independence shows that the relationship between children under five diarrhoea and regional variations is statistically significant at 1 percent level. Diarrhoea prevalence is higher in the Brong-Ahafo region (18.31 percent), followed by Eastern region (15.67 percent) and then Northern Region (14.72 percent), while low in Volta region (6.67 percent) and Western region (7.60 percent) as well as Greater Accra region (7.62 percent). The results corroborate with the percentage of diarrhoea among children under five years reported by Ghana Statistical Service (2014) in the Ghana Demographic and Health Survey (GDHS) that Brong Ahafo Region recorded the highest prevalence of diarrhoea due to the large cholera outbreak (17 percent), followed by Eastern region while Western region (7 percent), Greater Accra region (7 percent) and Volta region (7 percent) were the lowest respectively. Also, it confirms the findings of Noora *et al.* (2017) that Brong Ahafo Region recorded the highest prevalence of diarrhoea due to the large cholera outbreak in 2014.

Table 7: Prevalence of diarrhoea by regional variations

Regions	Child under five diarrhoea	
	No (%)	Yes (%)
Western	92.40	7.60
Central	90.54	9.46
Greater-Accra	92.38	7.62
Volta	93.33	6.67
Eastern	84.32	15.67
Ashanti	85.60	14.40
Brong-Ahafo	81.69	18.31
Northern	85.28	14.72
Upper- East	89.17	10.83
Upper-West	85.71	14.29
Total	87.70	12.30

Pearson chi2 = 70.4784 Pr = 0.000, Cramer’s V = 0.1153

Source: Author’s computation from the GSS *et al.* (2019).

Factors associated with households’ water and sanitation quality

Table 8 presents results on factors associated with households’ access to water quality (improved and unimproved) and sanitation quality (improved and unimproved). The results show that at 1 percent significant level, children living in the urban areas have access to improved water compared to their counterparts whi live in the rural areas. The results are consistent with UNICEF (2016) report, which established that most of the population without access to improved water sources are poor and live in the rural areas. Also, the results show a significant association between place of residence and type of sanitation facility and indicates that the proportion of children in the urban area have access to improved sanitation facilities such as flush toilet than those at the rural area. This explains the high diarrhoea prevalence among children under five in the rural areas of Ghana.

In addition, Table 8 illustrates that the significant association of mother's education and water quality at I percent indicating that access to quality or improved water increases with an increase in mother's education. The results show a higher proportion (76.5 percent) of mother's without education use unimproved drinking water compared to 90.8 percent of mothers who have secondary or higher. Same to the association between mother education and sanitation quality. Children whose mother have secondary education or higher have better (improved) sanitation (24 percent) compared to their counterparts whose mother have no education (2.8 percent). Moreover, there are regional difference in terms of access to improved water sources as shown in Table 8. The results indicate that Greater Accra is the region with the highest access to improved water source (97.1 percent), while the region with lowest access to improved water sources is Northern region (69.6 percent). This may be due to the fact that the region is poorly endowed with water bodies with a prolonged dry season.

Table 8: Factors associated with households' water and sanitation quality

Variables	Water Quality (%)		Sanitation Quality (%)	
	Unimproved	Improved	Unimproved	Improved
Residence				
Urban	5.2	94.8	70.7	29.3
Rural	23.6	76.4	97.7	2.3)
Total	16.3	83.7	86.9	13.1
	Chi2=314.79 (0.000), V=-0.244		Chi2=812.76 (0.000), V=-0.392	
Mother educ.				
None	23.5	76.5	97.2	2.8
JHS/SHS	19.1	80.9	92.8	7.2
Higher	9.2	90.8	76.0	24.0
Total	16.3	83.7	86.9	13.1
	Chi2= 163.391 (0.000), V= 0.176		Chi2= 452.441 (0.000), V= 0.292	
Wealth status				
Poorest	27.3	72.8	99.9	0.1
Poorer	26.8	73.2	98.7	1.3
Middle	7.3	92.8	93.5	6.5
Richer	1.1	98.9	75.2	24.8
Richest	0	100	36.0	64.0
Total	16.3	83.7	86.9	13.1
	Chi2=564.79 (0.000), V= 0.326		Chi2=2.0e+03 (0.000), V=0.61	
Region				
Western	19.1	80.9	85.2	14.8
Central	13.7	86.3	85.9	14.1
Greater	2.6	97.1	47.1	52.9
Accra	22.2	77.8	93.6	6.4
Volta	24.6	75.4	87.2	12.9
Eastern	8.1	91.9	73.1	26.9
Ashanti	16.1	83.9	94.6	5.42
Brong Ahafo	30.4	69.6	98.3	1.7
Northern	9.8	90.2	96.5	3.5
Upper East	4.8	95.2	95.2	4.8
Upper West	16.3	83.7	86.9	13.1
Total	Chi2=303.001(0.000), V =0.24		Chi2=883.404 (0.000), V=0.41	

Source: Author's computation from the GSS *et al.* (2019).

Factors associated with household water treatment

Table 9 presents results on factors associated with household water treatment. The results show a significant association between type of residence and treatment of water at the household level with a higher proportion household in urban areas more likely to treat water before drinking (7percent) compared those at the rural areas (6 percent). This explains that presumably, households in urban areas have knowledge of household water treatment than their counterparts. In addition, Table 8 illustrates that the significant association of mother's education and household water treatment at 1 percent indicating that the household's decision to treats water increases with an increase in mother's education. The results show a higher proportion (8.37 percent) of mother's with higher education treating their drinking water at the household or point-of-use compared to 4.61 percent of mothers with no education. The imply that education or limited knowledge and misinformation is a factor for low uptake and use of household water treatment. The result confirms findings of Allawala, Barry and Kayani (2017) that mother's education is a significantly factor of treatment of water.

With regards to the association between wealth status and household water treatment, decision to treat water increases as household wealth increases and this validates the hypothesis that as households' wealth status increases, then household decision to adopt defensive mechanism to maximise health utility (water treatment practices) increases as well (Alberini *et al.*, 1996). This imply that when household's income category changes or moves upwards, the more likely to respond to risk of contamination. Table 9 also show that sex of the household head is significantly associated with household water treatment. As shown in Table 9, children living in household where the head happen to be female, the more likely for water treater treatment compared to male household head. The reason for this is because females are more concerned for their child health than males.

Moreover, the type of household water source is significant associated to the defensive behavior in terms of treating water. The results indicate that households that rely on unimproved sources such as surface water (streams, dams, rivers) are more likely to treat water at the household level or point-of-use. The result shows a higher proportion of household water treatment among surface water users (16 percent) compared to 4.46 percent of piped/bottle water users. This is corroborated with the findings of Daniel *et al*. (2018) that the type of water sources households used (socio-environmental characteristics) appeared to influence their perception of their quality (psychosocial factor) and consequently influence their decision to treat water at the household level. In the same, the results as shown in Table 9 indicate that a significant association between distance to water source and household decision to adopts water treatment products. The results show a positive correlation between time spent to get to water source and decision to treats water at the household level. Thus, hhouseholds with travel times greater than 30 minutes have been shown to treat water.

Table 9: Factors associated with household water treatment

Variables	Water treatment (%)	
	No	Yes
Area of residence		
Urban	92.96	7.04
Rural	94.32	5.68
Chi2=4.1161 (0.042), Cramer's V = -0.0276		
Mother's education		
No education	95.39	4.61
Primary	91.74	8.26
Secondary	93.63	6.37
Higher	91.63	8.37
Chi2=17.9832 (0.000), Cramer's V= 0.0577		
Wealth status		
Poor	94.02	5.98
Middle	92.52	7.48
Richer	93.33	6.67
Richest	95.15	4.85
Chi2=10.6833 (0.030), Cramer's V =0.0445		
Sex of household head		
Male	94.24	5.76
Female	92.24	7.76
Chi2= 6.5193 (0.011), Cramer's V = 0.0347		
Type of water sources		
Piped/bottled	95.54	4.46
Well	95.30	4.70
Surface water	83.36	16.64
Other sources	80.52	19.48
Chi2=159.9910 (0.000), Cramer's V=0.1737		
Time to water source		
On premises	96.18	3.82
Less than 15 minutes	93.30	6.70
15-29 minutes	93.28	6.72
30mins and Above	88.12	11.88
Chi2 =55.0657 (0.000), Cramer's V =0.1021		
Region of residence		
Western	96.05	3.95
Central	93.28	6.72
Greater Accra	95.55	4.45
Volta	86.78	13.22
Eastern	91.58	8.42
Ashanti	92.19	7.81
Brong-Ahafo	92.74	7.26
Northern	95.14	4.86
Upper East	96.68	3.32
Upper West	96.96	3.04
Chi2=70.7995 (0.000), Cramer's V = 0.1145		

Source: Author's computation from the GSS *et al.* (2019).

Multivariate Analysis

The theoretical framework and model specification discussed in Chapter Three, guide this study to employ probit model and the endogenous treatment effect model in estimation the effect of household water treatment on under five diarrhoea in Ghana. Table 10 shows the marginal effect from the probit regression model, while Table 11 shows the results from the marginal effect from the endogenous treatment effect estimator. The regression based on the Wald test for endogeneity was tested and the hypothesis for the valid instrument cannot be rejected. The imply that the endogenous treatment effect estimator yield consistent results, therefore, the focus of discussion will be on the results in Table 11.

The post-estimation results for the probit model in Table 10 suggests that the probit model have a statistically significant predictive capability in explaining the effect of household water treatment on under fie diarrhoea. The mean of 3.20 for variance inflated factor (VIF) indicates that, the probit regression results in Table 10 has no omitted variables and that multicollinearity among the explanatory variables does not exist. Also, the R-square value of 0.40 established that 40 percent of the variation in under five child's diarrhoea is explained by the explanatory variables in Table 10. Though, the R-square for probit model is quite low, but according to Wooldridge (2010), low R-square values in regressions equation are common, especially for cross-sectional analysis. Though R-square is an indication of the goodness of fit of the model, the size of the R-square is not as important as the statistical and economic significance of the independent variables

(Wooldridge, 2010). Moreover, the linktest for _hat (P>|z|= 0.088) and _hatsq (P>|z|=0.782) shows that the model is correctly specified. The rule is that _hat should be significant but the _hatsq is significant then the model is not well specified. This means that we can, only by chance, find other predictors that are statistically momentous.

The results in Table 10, indicate that children living in household with an improved sanitation facility such as flush toilet, on average, likely to reduce diarrhoea among children under five by 18 percent compared to their counterparts who living in household without access to improved sanitation facilities. This result is consistent with the findings of Essilfie, Padi and Addor (2017) that access to improved sanitation facilities plays a vital role in protecting children against diarrhoea diseases. In contrast, drinking water supplied from improved sources rather increase under five diarrhoea risk by 19 percent. In the same vein, the results in Table 10 show that treating water at the household before drinking likely to increase the risk of child diarrhoea by 18 percent. This findings for improved water and treatment of water suggest that household's type main water source and the decision to treat water correlates to each other and this could bias the results.

Table 10: Probit regression results on household water treatment and child diarrhoea

Variable	Marginal Effects (dy/dx)	Delta-method (Robust Std.)	P>|Z|
Water (Unimproved=0) [rc]			
Improved	0.033***	0.0116	0.004
Treated water (No=0) [rc]			
Yes	0.037*	0.0209	0.076
Sanitation (Unimproved=0) [rc]			
Improved	-0.032**	0.0166	0.047

Table 10 Cont'D

Wealth Status (Poorest=0) [rc]			
Poorer	0.016	0.0144	0.274
Middle	0.015	0.0173	0.376
Richer	-0.022	0.0189	0.243
Richest	-0.034	0.0235	0.148
Mother's Age (<20 Years=0) [rc]			
20-34	-0.061**	0.0289	0.036
35 and Above	-0.063**	0.0297	0.035
Mother's Education (No=0) [rc]			
Primary	-0.008	0.0135	0.578
Secondary	-0.014	0.0126	0.252
Higher	-0.056**	0.0243	0.021
Child's Sex (Male=0) [rc]			
Female	-0.033***	0.0088	0.000
Child's Age	-0.015**	0.0031	0.000
Birthtype (Twin birth=0) [rc]			
Single	-0.044*	0.0255	0.086
Residence (Urban=0) [rc]			
Rural	-0.019	0.0126	0.139
Region (Brong-Ahafo=0) [rc]			
Western	-0.086***	0.0195	0.000
Central	-0.074***	0.0193	0.000
Greater Accra	-0.067***	0.0232	0.004
Volta	-0.108***	0.0183	0.000
Eastern	-0.007	0.0226	0.741
Ashanti	-0.009	0.0228	0.681
Northern	-0.027	0.0209	0.207
Upper East	-0.066***	0.0206	0.001
Upper West	-0.037	0.0224	0.101
Diagnostic Tests			
N		5301	
R^2		0.40	
Mean VIF		3.20	
Linktest		_hat: P>|z|=0.088* hatsq: P>|z|=0.782	

Notes *, ** and *** denote significance at 10%, 5% and 1% respectively
rc identifies the reference group for categorical variable
Source: Author's computation from the GSS *et al.* (2019).

The results in Table 10 is a counterintuitive, given that access to improved water and household water treatment should is expected to reduce the risk of diarrhoea prevalence among children under five. The reason for this counterintuitive is due to presence of possible or endogeneity simultaneity. The presence of endogeneity means there are unobserved heterogeneity that can bias the results. As a result, the endogenous treatment effect (ETE) model was with endogeneous regressors such as time to get to water, location of household main source of water and mother's education level to control the possible endogeneity. To correct the possible endogeneity of selection bias, the endogenous treatment effect model was adopted and the results is presented in Table 11. To confirm the endogeneity, Wald test of independence for the explanatory variables results is also presented in the latter part of Table 11. The Wald test result (rho=0: Chi2=1.02, Prob>Ch2=0.0310) show that the null hypothesis indicating that the explanatory variables are independent or exogenous is rejected and this confirms the possible endogeneity.

After correcting the issue of endogeneity, the result in Table 11 show that at 5 percent significant level, drinking from improved water sources rather to increase the risk of diarrhoea among children under five years by three percent and this effect persist in both models. As in Table 11, access to improved water does not reduces diarrhoea prevalence among children under five years in Ghana. The result suggests that the quality of water be compromised during collection, transport, and/or storage. This is consistent with a recent study that drinking from improved water sources rather increase the risk of diarrhoea among Ghanaian children under five years by 1.3 times (Nketiah-Amponsah &Afful-Mensah, 2017). This is also in line with Lechtenfeld (2012) that improved water increases the prevalence of diarrhoea in children by 4.6 percentage. In addition, the result validates studies that have argued that access to improved is not safe or free from fecal-contamination at the point-of-use (Pickering and Davis, 2012; Bain *et al*., 2014; and Shaheed *et al*., 2014).

The results in Table 11 also show that children living in households that treated water before usage are 30 percent less likely to suffer the risk of diarrhoea compared to their counter parts living in households that do not treat water. The result is consistent to the findings of Allawala, Barry and Kayani (2017) that households that treats water at the household level are 31.5 percent less likely to report and case of diarrhoea among children under five. The result also confirms Tan and Capuno (2012) report that household water treatment lowers the risk of diarrhoea children under five years by 4.26 percent. Other several studies that have reported household water treatment is effective in improving drinking water quality and diarrhoea reduction (Wright, Gundry & Conroy, 2004; Fewtrell *et al*., 2005; Clasen *et al*., 2007; Zin *et al*., 2013 and Heitzinger *et al*., 2015). The second stage regression of the Endogenous Treatment Effect (ETE) also indicated that location of water source and time spent to commute to a water source are importance components of water quality which influence household's decision to treat water.

Table 11: Endogenous treatment effect regression results on water treatment and child diarrhoea

Variables	Average Marginal Effects (dy/dx)	Delta-method (Robust. Std.)	P>|z|
Stage 1: Presence of diarrhoea			
Water (Unimproved=0) [rc]			
Improved	0.033***	0.0132	0.013
Treated water (No=0) [rc]			
Yes	-0.302*	0.1705	0.059
Sanitation (Unimproved=0) [rc]			
Improved	-0.043**	0.0182	0.018
Mother's Age (<20 Years=0) [rc]			
20-34	-0.069***	0.0257	0.007
35 and Above	-0.071***	0.0268	0.008

Table 12 Cont'D

Mother's educ. (No=0) rc			
Primary	-0.007	0.0138	0.589
Secondary	-0.019	0.0128	0.139
Higher	-0.039**	0.0321	0.021
Child's Sex (Male=0) rc			
Female	-0.036***	0.0093	0.000
Child's Age	-0.016***	0.0033	0.000
Birthtype (Twin birth=0) rc			
Single	-0.052**	0.0235	0.028
Residence (Urban=0) rc			
Rural	-0.007	0.0109	0.509
Region (Brong-Ahafo=0) rc			
Western	-0.100***	0.0205	0.000
Central	-0.075***	0.0201	0.000
Greater Accra	-0.085***	0.0233	0.004
Volta	-0.114 ***	0.0212	0.000
Eastern	-0.009	0.0208	0.643
Ashanti	-0.017	0.0212	0.424
Northern	0.037**	0.0192	0.053
Upper East	-0.076***	0.0208	0.000
Upper West	-0.047**	0.0217	0.032
_cons	0.357	0.0409	0.000
Stage 2: Treatment of Water			
Base category is don't treat			
Location of water (Inside=0) rc			
Outside dwelling	4.664	1.2045	0.000
Time to water source	0.005	0.0012	0.000
_con	-6.389	1.2334	0.000
Diagnostic Tests			
Observations (N)=5301			
hazard lambda	0.175	0.0812	0.0310
rho	0.521		
sigma	0.337		

Wald Test of Indep. Equation :(rho = 0): chi2=1.02 Prob > chi2 = 0. 0310

Notes *, ** and *** denote significance at 10%, 5% and 1% respectively
rc identifies the reference group for categorical variable
Source: Computed from the 2014 GDHS (2019).

With reference to improved sanitation, the result in Table 11 indicates that children living in household with access to improved sanitation facilities such as flush toilet are four percent less likely to report any case of diarrhoea disease remains an important intervention for preventing diarrhoea compared children living in household without improved sanitation facilities. The result collaborates with the findings of Annim and Imai (2014), Kumar and Vollmer (2013); and Essilfie, Padi and Addor (2017). According these studies, children living in households with improved flush toilet have better health gains than children living in households with other type of toilet facilities which are not improved.

With respect to mother's age and educational, the results as shown in Table 11 show that children whose mother's age is 20 years and above are less likely to suffer the risk of diarrhoea with a varying effect compared to their counterparts whose mothers age below 20 years. This imply that women who are not matured are vulnerable least likely to be able to properly take care of themselves and protect their children from some preventable diseases such as diarrhoea. Mothers with secondary education or higher are on average, three percent and five percent less likely to suffer the risk of diarrhoea among children under five years compared to mothers with no schooling. The result is in line with the findings of Agyemang (2013); Kumi-Kyereme and Amo-Adjei (2016); Tampah-Naah (2019) who found maternal education to be significant in decreasing child mortality-related diseases such as diarrhoea, ARI and fever in Ghana. This imply that educated mothers are better informed and are in better position to protect their children from childhood diseases that are associated with unsafe water, unimproved sanitation facilities and poor hygiene practice. that may breakout from such conditions compared mothers who are uneducated individuals.

Moreover, the results show that child's age and sex are significant factors that are associated with diarrhoea. As shown in Table 11, at 1 percent significant level, as child's age increases, the risk of diarrhoea reduces by two percent. This explains that the prevalence of diarrhoea more likely to be higher among children who are very young, while it reduces as the child grows. The result is in consonance with Essilfie, Padi and Addor (2017) that the likelihood of a child suffering from diarrhoea reduces as the child progresses in age.

For the sex of the child, the result indicates that female child are four percent less likely to suffer the risk of diarrhoea compared to their counterparts who are males. This imply that, in Ghana, children under five who are males the most risk of diarrhoea than females. The reason this gender difference is due to the biological factors. For instance, males are aggressive and exposure to wander or play in insanity environment than females and this puts much burden on them.

Regarding to whether the child is a twin or not, the result indicates that on average children happened to be twins are likely to suffer the risk of diarrhoea than children born of single births type. This explain that children living in household with siblings are more likely to compete for the limited resource available with other members. However, the place of residence (rural) showed a negative but insignificant relationship with child under five diarrhoea.

Concerning regional dummies, the results showed insignificant results with exception of Western, Central, Greater Accra, Volta, Upper-East, and Upper-West Region. Using the Brong-Ahafo as the base category, the results indicate that, children residing in the Western, Central, Greater Accra and Volta, Upper-East, and Upper-West regions are likely to lower the risk of diarrhoea compared to children living in Brong-Ahafo region.

Chapter summary

This chapter presented a detailed analysis of how improve water sources, household water treatment and sanitation affect child under five diarrhoea. First to be considered were the descriptive statistics, which helped to give a cursory look of how household level characteristics relate to child health in Ghana. This is followed by multivariate regression analysis, which give a firm basis on which to conclude that household water treatment and improved sanitation infrastructure lead to proper child health in terms of diarrhoea of diarrhoea reduction.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Introduction

This chapter presents the summary, conclusion and policy recommendations as well as direction for future research.

Summary

Improving access to safe water, adequate sanitation and proper hygiene are on the frontline of efforts to achieve the anticipated 2030 Sustainable Development Goal 3 and 6. Notwithstanding the numerous benefits associated with access to safe water, particularly at the household level, unsafe drinking water remains a big issue of concern in Ghana, where waterborne diseases, including diarrhoea cause a great harm among children under five. To overcome these challenges, household water treatment is widely recognized in ensuring safe water and prevention of diarrhoea. It is in the light of this that the current examined the effect of household water treatment on under five diarrhoea in Ghana. Using the 2014 round of the Ghana Demographic and Health Survey (GDHS) dataset, this study adopted the Grossman (1972), the generalized Grossman model by Jacobson (2000) and Alberini *et al.* (1996) defensive and illness model as the theoretical framework based on which the model for the study was specified.

The part of the results presented the descriptive statistics of the variable used for the study and this included the univariate and bivariate analysis. Using the Chi-square analysis and Cramer’s V statistical test, the bivariate analysis touches on the relationship of selected demographics and under five diarrhoea. Further, in explaining the effect of improved water source, household water treatment and improved sanitation on child diarrhoea, the multivariate regression analysis results presented. The results from the descriptive analysis indicated that out of a sample of 5301, the average age for children in months was about 28 months, while mother's age was 31 years. In addition, the results suggest that on average children spend 21 and 19 minutes to get to a water source and sanitation facility respectively.

The findings from the univariate analysis also indicated 12 percent of children under five years had diarrhoea. This explains that the prevalence of diarrhoea is reducing compared to 20 percent recorded in 2008, however, still remains a big challenge in Ghana. Again, the results indicated that a greater number (45 percent) of children living in households use well water as their main source of water, while about 33 percent live in household without a toilet facility implying that they use or open field for defecation, however, majority (93 percent) of households do not treat drinking water.

With reference to the objective of the study, the bivariate analysis indicated that improved water source, household water treatment and improved sanitation of are statistically associated to under five diarrhoea. the results showed that household without improved water and sanitation facility as well as do not treat water experienced a higher risk of diarrhoea. other variables such as mother's age and educational level, sex and age of the child, and type of place of residence are associated with diarrhoea diseases among children under five years. Accordingly, children within the age group of 18-23 months were found to be more prone to the risk of diarrhoea due to the fact that they are newly introduced to solid feeding at this period of their age. Concerning factor associated with household decision to adopt household water treatment products, the results showed that main water source, mother's education, wealth status, place of residence, regional difference, distance to water sources all factors that influence household water treatment.

In accordance to the first the hypothesis of the study, the multivariate regression results after correcting the endogeneity showed that household's access to improved water significantly increases diarrhoea among children under five. This confirms numerous studies that found that not all water from improved sources are safe. In relation to the hypothesis, the multivariate regression showed that household water treatment is significant in reducing diarrhoea disease among children under five years. Children living in households where water is treated before drinking are less likely to suffer the risk of diarrhoea compared those living in household without treating water.

The second stage regression of the Endogenous Treatment Effect (ETE) also indicated that location of water source and time spent to commute to a water source are importance components of water quality which influence household's decision to treat water before usage at the household level. The result suggests that the quality of water be compromised during collection, transport, and/or storage. With reference to the third hypothesis, access to improved sanitation facilities was found to be significantly reduces the likelihood of diarrhoea diseases among children under five. The multivariate regression analysis also, showed that, other covariates such as mother's age, mother's education, child's age, child's sex were found to be significantly associated diseases among children under five years.

Conclusion

Following the major findings from the study, the following conclusions could be made. Firstly, drinking from improved water source rather increases the risk of diarrhoea among children under five years in Ghana. Following the WHO and UNICEF (2017) classification of water, access to piped water, boreholes or tube wells, protected dug wells, protected springs, rainwater, and packaged delivered water (improved water) increase diarrhoea diseases among children under five years old in Ghana. This confirms not all water from improved sources are safe.

Secondly, there is conclusive evidence that adopting simple and inexpensive household water treatment methods, such as filtration, radiation disinfection, boiling or chlorine, or simply providing enclosed protected containers are capable of dramatically improving the quality of water at the household level and reducing the risks of diarrhoea disease and death in populations of children under five years in Ghana. This confirms that household water treatment ensures clean and safe water at the household level or point-of-use and limits the spread of diarrhoea disease

Thirdly, children living in households with quality of sanitation facilities (improved) reduces diarrhoea and positively affects children under five years old health. This also confirms the fact that, adequate access to improved sanitation reduces the tolls of diarrhoea diseases and malnutrition among children under five.

Finally, individual level characteristics such as mother's age, education, child's age, sex, and birth type were found to be key predictors of under five diarrhoea. The study concludes that, although mother's education is one of the prominent factors that significantly reduces the occurrence of the prevalence of diarrhoea among children below age five in Ghana, it is only significant for mothers with higher educational level.

The novelty of this study from most research on children's under five diarrhoea status is that, unlike other studies in Ghana, this study sheds more light in understanding the lead role that household water treatment plays in water quality improvement and diarrhoea among children under five reduction by considering the both household level and individual characteristics.

Although, most of the studies in the literature had similar conclusion, the study explored more detailed analysis of improved water and household water treatment by correcting the issue of endogeneity. This enables the assessment of the extent to which improved water source, household water treatment, improved sanitation facilities as well as characteristics of children, their mother's, and household characteristics are associated with diarrhoea among children under five in Ghana.

Recommendations

Considering the findings and conclusion of the study, the following policies are recommended for consideration.

Household water treatment promotion: The Government should invest more heavily in scaling-up programs and policies needed to communicate the importance of treating drinking water for families currently lacking reasonable-quality water supply in order to prevent waterborne illness and associated diarrhea and other related diseases. Also, the health promotion unit of Ghana Health Service (GHS) through community nurses and the community-based health planning and services, should advocate and intensify education programs with appropriate training and follow-up on household water treatment.

Improved water expansion: It is advised that Government through the Ghana Standards Authority (GSA), Ghana Water Company Limited (GWCL) and the Community Water and Sanitation Agency (CWSA) should regularly monitor sachet water and piped water as well as other improved water sources for its microbial quality to ensure that Ghanaians are offered clean and safe drinking water in order to curb the incidence of diarrhoea among children. In addition, policies aimed at addressing household deficiency in water demand should focus on making more resources available to the Ghana Water Company Limited (GWCL) and the Community Water and Sanitation Agency so as to achieve more coverage of water accessible to deprived rural households where surface water is their main source drinking water

Improved sanitation: In order to improve sanitation and hygiene, it is advised that Government through the Ministry of Local Government and Rural Development (MLFRD) should market the practice of safe disposal of faecal and waste in particular, as a concept that has public health benefits and not merely a toilet facility. This can be done by strengthening the community's role in environmental sanitation and hygiene such as monthly communal cleaning programme, town council and by bye-laws against open defecation.

Encourage and promote maternal education: To decrease the prevalence of childhood diarrhoea in the country, the Government through the Ministry of Education (MoE) should promote higher education among females by increasing cut-off grades for females entering senior high schools and tertiary institutions. Also, the health promotion unit of Ghana Health Service

(GHS) through community nurses and the community-based health planning and services should offer antenatal, post-natal and more educative programmes are required for mothers, particularly those at the rural areas with low level of education on how to attain better health outcomes of their children.

Child under five health Policy: Although some progress has been made, there are several challenges still to be addressed with regards to the prevalence of diarrhoea among children under five years in some regions. To this end, the various Ghana Health Directorates could design context-based interventions within the administrative regions to adequately target populations at risk. Also, expansion of such interventions that led to a large reduction of under five morbidity and mortality in the previous years (2007-2015) can be a positive direction to reaching the Sustainable Development Goal (SDG) of reducing under-five mortality rate to 25/1000 live births by 2030.

Suggestion for the Future Research

This study examined the association between improved water source, household water treatment, improved sanitation and under-five's child diarrhoea in Ghana. However, diarrhoea is not the only disease caused by unsafe water and unsafe environmental sanitation conditions, therefore, researcher may as well consider expanding this current study by exploring the effect of household water treatment on other common diseases such as trachoma, typhoid, cholera.

Also, future studies can improve upon this study by using longitudinal or randomized control trials to minimize self-reporting bias in the DHS and scrutinize the actual causalities.

REFERENCES

Abbam, A., & Carsamer, E. (2017). Household choice of safe drinking water in Ghana. *Ghanaian Journal of Economics*, *5* (1), 81-95.

Adams, E. A., Boateng, G. O., & Amoyaw, J. A. (2016). Socioeconomic and demographic predictors of potable water and sanitation access in Ghana. *Social Indicators Research*, *126* (2), 673-687.

Adane, M., Mengistie, B., Medhin, G., Kloos, H., & Mulat, W. (2017b). Piped water supply interruptions and acute diarrhea among under-five children in Addis Ababa slums, Ethiopia: A matched case-control study. *PloS one*, *12* (7).

Adua, E., Frimpong, K., Li, X., & Wang, W. (2017). Emerging issues in public health: a perspective on Ghana's healthcare expenditure, polices and outcomes, *EPMA Journal, 8 (3),* 197-206.

Agbadi, P., Darkwah, E., & Kenney, P. L. (2019). A Multilevel Analysis of Regressors of Access to Improved Drinking Water and Sanitation Facilities in Ghana. *Journal of Environmental and Public Health*, *2019*.

Agrawal, V. K., & Bhalwar, R. (2009). Household water purification: Low-cost interventions. *Medical Journal of Armed Forces India*, *65* (3), 260-263.

Agyemang, M. (2013). *Effect of Education on the Health of Children Under Five Years: Some Evidence from Ghana* (Doctoral dissertation, University of Ghana).

Alberini, A., Eskeland, G.S., Krupnick, A. and McGranahan, G. (1996). Determinants of diarrheal disease in Jakarta. Water Resources Research. 32, 2259-2269.

Allawala, F. I., Barry, S. J., & Kayani, M. S. (2017). Diarrheal Diseases Due to Unsafe Drinking Water in Pakistan: A Defensive Behaviour Approach.

Akpalu, W. (2012). Travel Distance and Household's Demand for Water in Ghana. CEERAC Working Paper No. 006, Center for Environmental Economics Research & Consultancy, Ghana.

Annim, S. K., & Imai, K. S. (2014). *Nutritional status of children, food consumption diversity and ethnicity in Lao PDR*. Research Institute for Economics and Business Administration, Kobe University.

Anyorikeya, M., Ameme, D. K., Nyarko, K. M., Sackey, S. O., & Afari, E. (2016). Trends of diarrhoeal diseases in children under five years in the War Memorial Hospital-Navrongo, Ghana: 2010-2013. *The Pan African Medical Journal*, *25* (Suppl).

Appiah-Effah, E., Duku, G. A., Azangbego, N. Y., Aggrey, R. K. A., Gyapong-Korsah, B., & Nyarko, K. B. (2019). Ghana's post-MDGs sanitation situation: an overview. *Journal of Water, Sanitation and Hygiene for Development*, *9* (3), 397-415.

Armah, F. A. (2014). Relationship between coliform bacteria and water chemistry in groundwater within gold mining environments in Ghana. *Water Quality, Exposure and Health*, *5* (4), 183-195.

Armah, F. A., Ekumah, B., Yawson, D. O., Odoi, J. O., Afitiri, A. R., & Nyieku, F. E. (2018). Access to improved water and sanitation in sub-Saharan Africa in a quarter century. *Heliyon*, *4* (11), e00931.

Arnold, B. F., & Colford Jr, J. M. (2007). Treating water with chlorine at point- of-use to improve water quality and reduce child diarrhea in developing countries: a systematic review and meta-analysis. *The American journal of tropical medicine and hygiene*, *76* (2), 354-364.

Asamoah, A., Ameme, D. K., Sackey, S. O., Nyarko, K. M., & Afari, E. A. (2016). Diarrhoea morbidity patterns in Central Region of Ghana. *The Pan African Medical Journal*, *25* (Suppl 1).

Bain, R., Cronk, R., Wright, J., Yang, H., Slaymaker, T., & Bartram, J. (2014). Fecal contamination of drinking-water in low-and middle-income countries: a systematic review and meta-analysis. *PLoS medicine*, *11*(5).

Bartram, J., & Cairncross, S. (2010). Hygiene, sanitation, and water: forgotten foundations of health. *PLoS Medicine, 7* (11).

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., De Onis, M., ... & Uauy, R. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet, 382* (9890),427-451.

Bloom, D. E., and D. Canning (2000): "The Health and Wealth of Nations," *Science*, *287*, 1207–1209.

Buono, J. L., Mathur, K., Averitt, A. J., & Andrae, D. A. (2017). Economic burden of irritable bowel syndrome with diarrhea: retrospective analysis of a US commercially insured population. *Journal of Managed Care & Specialty Pharmacy*, *23* (4), 453-460

Cairncross, S., Hunt, C., Boisson, S., Bostoen, K., Curtis, V., Fung, I. C., & Schmidt, W. P. (2010). Water, sanitation and hygiene for the prevention of diarrhoea. *International journal of Epidemiology*, *39* (suppl_1), i193- i205.

Cha, S., Kang, D., Tuffuor, B., Lee, G., Cho, J., Chung, J., ... & Oh, C. (2015). The effect of improved water supply on diarrhea prevalence of children under five in the Volta region of Ghana: a cluster-randomized controlled trial. *International journal of Environmental Research and Public Health*, *12* (10), 12127-12143.

Clasen, T. F., & Mintz, E. D. (2004). International network to promote household water treatment and safe storage. *Emerging Infectious Diseases*, *10* (6), 1179.

Clasen, T., Schmidt, W. P., Rabie, T., Roberts, I., & Cairncross, S. (2007). Interventions to improve water quality for preventing diarrhoea: systematic review and meta-analysis. *British Medical Journal*, *334* (7597), 782.

Clasen, T. F., Alexander, K. T., Sinclair, D., Boisson, S., Peletz, R., Chang, H. H, ... & Cairncross, S. (2015). Interventions to improve water quality for preventing diarrhoea. *Cochrane Database of Systematic Reviews*, (10).

Cohen, A., & Colford, J. J. M. (2017). Effects of boiling drinking water on diarrhoea and ppathogen-specific infections in low-and middle-income countries: a systematic review and meta-analysis. *The American Journal of Tropical Medicine and Hygiene*, *97* (5), 1362-1377.

Daniel, D., Marks, S. J., Pande, S., & Rietveld, L. (2018). Socio-environmental drivers of sustainable adoption of household water treatment in developing countries. *Nature Partner Journals, Clean Water*, *1* (1), 1-6.

Dekoleadenu, D. J. (2015). *Source of Household Drinking Water and Diarrhoea among Children Under Five Years in Ghana* (Doctoral dissertation).

Dessie, H., & Kishan, N. (2014). MHD effects on heat transfer over stretching sheet embedded in porous medium with variable viscosity, viscous dissipation and heat source/sink. *Ain Shams Engineering Journal*, *5* (3), 967-977.

Doocy, S., Tappis, H., Villeminot, N., Suk, A., Kumar, D., Fazal, S., ... & Pietzsch, S. (2018). Point-of-use water treatment improves recovery rates among children with severe acute malnutrition in Pakistan: results from a site-randomized trial. *Public Health Nutrition*, *21* (16), 3080-3090.

Ercumen, A., Naser, A. M., Unicomb, L., Arnold, B. F., Colford Jr, J. M., & Luby, S. P. (2015). Effects of source-versus household contamination of tube well water on child diarrhea in rural Bangladesh: a randomized controlled trial. *PloS One*, *10* (3).

Esrey, S. A., Potash, J. B., Roberts, L., & Shiff, C. (1991). Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bulletin of the World Health Organization*, *69* (5), 609.

Essilfie, G., Padi, A., & Addor, J. A. (2017). A Probit Model Version of Water and Sanitation as Predictors of Child Diarrhoea in Ghana. *Asian Journal of Economics, Business and Accounting*, 1-13.

Fenta, H. M., Workie, D. L., Zike, D. T., Taye, B. W., & Swain, P. K. (2019). Determinants of stunting among under-five years children in Ethiopia from the 2016 Ethiopia demographic and Health Survey: Application of ordinal logistic regression model using complex sampling designs. *Clinical Epidemiology and Global Health.*

Fewtrell, L., Kaufmann, R. B., Kay, D., Enanoria, W., Haller, L., & Colford Jr, J. M. (2005). Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *The Lancet Infectious Diseases*, *5* (1), 42-52.

Fielmua, N., Akudugu, M. A., & Dugle, G. (2019). Water, sanitation and rural livelihoods nexus: an exploratory study of Wogu in the Upper West Region of Ghana. *Ghana Journal of Development Studies*, *16* (2), 199-219.

Frank-Briggs, A. I. (2012). Introduction and classification of childhood diarrhoea. In *Current concepts in colonic disorders*. Intech Open.

Geremew, A., Mengistie, B., Mellor, J., Lantagne, D. S., Alemayehu, E., & Sahilu, G. (2018). Appropriate household water treatment methods in Ethiopia: household use and associated factors based on 2005, 2011, and 2016 EDHS data. *Environmental Health and Preventive Medicine*, *23* (1), 46.

Geremew, A., Mengistie, B., Mellor, J., Lantagne, D. S., Alemayehu, E., & Sahilu, G. (2019). Consistent point-of-use water chlorination among households using unimproved water sources and treatment preference in Eastern Ethiopia. *International Journal of Environmental Health Research*, *29* (6), 686-701.

Ghana Statistical Service (2019). Ghana Fact Sheet: People and Society. Retrieved from http://www.statsghana.gov.gh/ghfactsheet.php.

Ghana Statistical Service (GSS) and Macro International Inc. (2015). *Ghana Demographic and Health Survey 2014*, GSS and MI, Calverton, MA, USA.

Godfrey, S., Labhasetwar, P., Wate, S., & Pimpalkar, S. (2011). How safe are the global water coverage figures? Case study from Madhya Pradesh, India. *Environmental Monitoring and Assessment*, *176* (1-4), 561-574.

Grossman, M. (1972). On the concept of health capital and the demand for health. *Journal of Political Economy*, *80* (2), 223-255.

Guarino, A., Guandalini, S., & Vecchio, A. L. (2015). Probiotics for prevention and treatment of diarrhea. *Journal of Clinical Gastroenterology*, *49*, S37-S45.

Günther, I., & Fink, G. (2011). *Water and sanitation to reduce child mortality: The impact and cost of water and sanitation infrastructure*. The World Bank.

Hausman, J. A., & Wise, D. A. (1978). A conditional probit model for qualitative choice: Discrete decisions recognizing interdependence and heterogeneous preferences. *Econometrica: Journal of the econometric society*, 403-426.

Heckman, J.J. (1976). The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. *Annals of Economics and Social Measurement 5* (4), 475-492.

Heckman, J.J. (1978). Dummy endogenous variables in simultaneous equation system. *Econometrica 46* (4), 931-959.

Heitzinger, K., Rocha, C. A., Quick, R. E., Montano, S. M., Tilley Jr, D. H., Mock, C. N., ... & Hawes, S. E. (2015). “Improved” but not necessarily safe: an assessment of faecal contamination of household drinking water in rural Peru. *The American Journal of Tropical Medicine and Hygiene, 93* (3), 501-508.

Hong, R., Banta, J.E., & Kamau, J.K. (2007). Effect of maternal HIV infection on child survival in Ghana. *Journal of Community Health, 32* (1), 21-36.

Hong, R., Ruiz-Beltran, M. (2007). Impact of prenatal care on infant survival in Bangladesh. *Maternal and Child Health Journal, 11* (2), 199–206.

Hulland, K., Martin, N., Dreibelbis, R., Valliant, J. D., & Winch, P. (2015). What factors affect sustained adoption of safe water, hygiene and sanitation technologies? A systematic review of literature. *EPPI-Centre, Social Science Research Unit, UCL Institute of Education, University College London, London*.

Hunter, P. R. (2003). Drinking water and diarrhoeal disease due to Escherichia coli. *Journal of Water and Health, 1* (2), 65-72.

Hutton, G., & Chase, C. (2016). The knowledge base for achieving the sustainable development goal targets on water supply, sanitation and hygiene. *International Journal of Environmental Research and Public Health, 13* (6), 536.

Jacobson, L. (2000). The family as producer of health—an extended Grossman model. *Journal of Health Economics, 19* (5), 611-637.

Just, M. R., Carden, S. W., Li, S., Baker, K. K., Gambhir, M., & Fung, I. C. H. (2018). The impact of shared sanitation facilities on diarrheal diseases with and without an environmental reservoir: a modeling study. *Pathogens and Global Health, 112* (4), 195-202.

Keats, A. (2018). Women's schooling, fertility, and child health outcomes: Evidence from Uganda's free primary education program. *Journal of Development Economics*, *135*, 142-159.

Kier, P. P. D., & Dai, Y. C. (2018). Mothers' knowledge, attitudes and practices on preventing diarrhoea in Juba, South Sudan. *South Sudan Medical Journal*, *11* (3), 60-64.

Kipp, A. M., Blevins, M., Haley, C. A., Mwinga, K., Habimana, P., Shepherd, B. E., ... & Vermund, S. H. (2016). Factors associated with declining under-five mortality rates from 2000 to 2013: an ecological analysis of 46 African countries. *BMJ open*, *6* (1), e007675.

Krupnick, A., Alberini, A., McGranahan, G., & Eskeland, G. S. (1996). Determinants of Diarrhoel Disease in Jakarta. *World Bank Policy Research Papers*, *1568*, 1-3.

Kumar, S., & Vollmer, S. (2013). Does access to improved sanitation reduce childhood diarrhea in rural India? *Health Economics*, *22* (4), 410-427.

Kumi-Kyereme, A. and Amo-Adjei, J. (2016). Household wealth, residential status and the incidence of diarrhoea among children under-five years in Ghana. Journal of Epidemiology and Global Health, 6, pp. 131-140.

Lantagne, D. S., & Clasen, T. F. (2012). Use of household water treatment and safe storage methods in acute emergency response: case study results from Nepal, Indonesia, Kenya, and Haiti. *Environmental Science & Technology*, *46* (20), 11352-11360.

Lechtenfeld, T. (2012). Why does piped water not reduce diarrhea for children? Evidence from urban Yemen. (Courant Research Centre: Discussion Papers). Georg-August-Universitat Gottingen.

Lee, G., Yori, P., Olortegui, M. P., Pan, W., Caulfield, L., Gilman, R. H., ... & Kosek, M. (2012). Comparative effects of vivax malaria, fever and diarrhoea on child growth. International Journal of Epidemiology, *41* (2), 531-539.

MacDonald, L. (2017). *Household Water Treatment and Safe Storage in Ghana: An Interim Solution?* (Doctoral dissertation, Johns Hopkins University).

Maddala, G. (1983). *Limited-Dependent and Qualitative Variables in Econometrics.* New York: Cambridge University Press,

Mariwah, S. (2018). Sanitation: the neglected Siamese twin of water in achieving the millennium development goals (MDGs) in Ghana. *GeoJournal*, *83* (2), 223-236.

Mengistie, Bezatu, Yemane Berhane, and Alemayehu Worku (n.d). "Household water treatment with chlorine reduces incidence of diarrhea among under-five children in rural Ethiopia: A cluster randomized controlled trial"

National Research Council. (2004). *Children's health, the nation's wealth: assessing and improving child health*. National Academies Press.

Nkansah, F. (2014). *The Effect of Improved Sanitation on Child Health in Ghana* (Doctoral dissertation, University of Ghana).

Nketiah-Amponsah, E., & Afful-Mensah, G. (2017). Source of drinking water and the prevalence of diarrhoea among children aged under-five in Ghana-recent evidence. *International Journal of Economics and Business Research*, *13* (3), 275-302.

Noora, C. L., Issah, K., Kenu, E., Bachan, E. G., Nuoh, R. D., Nyarko, K. M., ... & Letsa, T. (2017). Large cholera outbreak in Brong Ahafo region, Ghana. *BMC Research Notes*, *10* (1), 389.

Onjala, J., Ndiritu, S. W., & Stage, J. (2014). Risk perception, choice of drinking water and water treatment: evidence from Kenyan towns. *Journal of Water, Sanitation and Hygiene for Development*, *4* (2), 268-280.

Osumanu, I. K. (2007). Household environmental and behavioural determinants of childhood diarrhoea morbidity in the Tamale Metropolitan Area (TMA), Ghana. *Geografisk Tidsskrift-Danish Journal of Geography, 107* (1), 59-68.

Padilla, D. ((2012). The Effectiveness of Water, Hygiene, and Sanitation Interventions in Lowering Diarrheal Morbidity Across the Globe: A Systematic Review and Qualitative Analysis of Relevant Primary Literature. Arizona: Arizona State University.

Pickering, A. J., & Davis, J. (2012). Freshwater availability and water fetching distance affect child health in sub-Saharan Africa. *Environmental Science & Technology*, *46* (4), 2391-2397.

Pindyck, R. S., & Rubinfeld, D. L. (1991). Econometric Models and Economic Forecast, McGraw-Hills, New York. *Convergence and Divergence in Europe: Polish and Ukrainian Cases*, *660*.

Pullan, R. L., Freeman, M. C., Gething, P. W., & Brooker, S. J. (2014). Geographical inequalities in use of improved drinking water supply and sanitation across sub-Saharan Africa: mapping and spatial analysis of cross-sectional survey data. *PLoS Medicine*, *11* (4).

Schiller, L. R., Pardi, D. S., Spiller, R., Semrad, C. E., Surawicz, C. M., Giannella, R. A., ... & Sellin, J. H. (2014). Gastro 2013 APDW/WCOG Shanghai working party report: chronic diarrhea: definition, classification, diagnosis. *Journal of Gastroenterology and Hepatology*, *29* (1), 6-25.

Shaheed, A., Orgill, J., Montgomery, M. A., Jeuland, M. A., & Brown, J. (2014). Why? Improved? Water Sources Are Not Always Safe. *Bulletin of the World Health Organization*, *92*, 283-289.

Shields KF, Bain RES, Cronk R, Wright JA, Bartram J. (2015). Association of supply type with fecal contamination of source water and household stored drinking water in developing countries: a bivariate meta-analysis. *Environmental Health Perspectives, 123* (12): 1222e31.

Shier, R. P., Dollimore, N., Ross, D. A., Binka, F. N., Quigley, M., & Smith, P. G. (1996). Drinking water sources, mortality and diarrhea morbidity among young children in Northern Ghana. *Tropical Medicine & International Health*, *1* (3), 334-341.

Singh K, Bloom S, Brodish P. (2015). Gender equality as a means to improve maternal and child health in Africa. *Health Care for Women International*. *36* (1):57–69.

Sobsey, M. D., Stauber, C. E., Casanova, L. M., Brown, J. M. & Elliott, M. A. (2008). Point of use household drinking water filtration: a practical, effective solution for providing sustained access to safe drinking water in the developing world. *Environmental Science Technology*. *42*, 4261– 4267.

Steele, R. (2018). Drinking Water, Sanitation and Hygiene in Schools: Global Baseline Report 2018. WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene. *UNICEF*.

Strauss, J., and D. Thomas (1998): “Health, Nutrition and Economic Development,” *Journal of Economic Literature, 36*, 766-817.

Tampah-Naah, A. M. (2019). Maternal and child level factors associated with childhood (0-23 months) diarrhoea in Ghana: a pooled analysis of national representative datasets. *Ghana Journal of Development Studies*, *16* (2), 157-177.

Tampah-Naah, A. M., Osman, A., & Kumi-Kyereme, A. (2019). Geospatial analysis of childhood morbidity in Ghana. *PloS One*, *14* (8).

Tan, C. A. R., & Capuno, J. J. (2012). *Household decisions and child health: Estimating the links between water treatment and the incidence of diarrhea using non-recursive two-equation causal models* (No. 2012-02). UPSE Discussion Paper.

Troeger, C., Blacker, B. F., Khalil, I. A., Rao, P. C., Cao, S., Zimsen, S. R., ... & Alvis-Guzman, N., (2018). Estimates of the global, regional, and national morbidity, mortality, and aetiologies of diarrhoea in 195 countries: a systematic analysis of the Global Burden of Disease Study 2016. *The Lancet Infectious Diseases*, *18* (11), 1211-1228.

UN Department of Economic and Social Affairs, Population Division. (2017). World Population Prospects: The 2017 Revision. Key Findings and Advance Tables. Working paper no. ESA/P/WP/248.

UN-IGME (2019). Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation: Levels & Trends in Child Mortality Report, 2019. United Nations Children's Fund, New York.

United Nations Staff, Dominick Salvatore, & United Nations. Dept. of International Economic. (1989). *African Development Prospects: A Policy Modeling Approach*. Taylor & Francis.

Usman, M. A., Gerber, N., & von Braun, J. (2019). The impact of drinking water quality and sanitation on child health: Evidence from rural Ethiopia. *The Journal of Development Studies*, *55* (10), 2193-2211.

Van Malderen, C., Amouzou, A., Barros, A. J., Masquelier, B., Van Oyen, H., & Speybroeck, N. (2019). Socioeconomic factors contributing to under- five mortality in sub-Saharan Africa: a decomposition analysis. *BMC Public Health*, *19* (1), 760.

Victora, C. G., De Onis, M., Hallal, P. C., Blössner, M., & Shrimpton, R. (2010). Worldwide timing of growth faltering: revisiting implications for interventions. *Pediatrics*, *125* (3), e473-e480.

Waddington, H., Snilstveit, B., White, H., & Fewtrell, L. (2009). Water, sanitation and hygiene interventions to combat childhood diarrhoea in developing countries. *New Delhi: International Initiative for Impact Evaluation*.

Wagner, E. G., Lanoix, J. N., & World Health Organization. (1958). *Excreta Disposal for Rural Areas and Small Communities*. World Health Organization.

Wardlaw, T., Salama, P., Brocklehurst, C., Chopra, M., & Mason, E. (2010). Diarrhoea: why children are still dying and what can be done. *The Lancet*, *375* (9718), 870-872.

Wierzba, T. F., & Muhib, F. (2018). Exploring the broader consequences of diarrhoeal diseases on child health. *The Lancet Global Health*, *6* (3), e230-e231.

Wolf, J., Hunter, P. R., Freeman, M. C., Cumming, O., Clasen, T., Bartram, J, … & Prüss-Ustün, A. (2018). Impact of drinking water, sanitation and handwashing with soap on childhood diarrhoeal disease: updated meta-analysis and meta-regression. *Tropical Medicine & International Health*, *23* (5), 508-525.

Wooldridge, J. M., (2010). *Econometric analysis of cross section and panel data*. MIT press.

World Bank (2006). Africa Regional Office. Office of the Chief Economist, World Bank. Africa Regional Office. Operational Quality, Knowledge Services & World Bank. Development Data Group. *Africa Development Indicators*. World Bank Publications.

World Health Organisation (2018). Joint Monitoring Programme report retrieved from https://www.newsghana.com.gh/unicef-who-report-says-most-children-die-from-diarrhoea/

World Health Organization (2019). *Water, Sanitation, Hygiene and Health: A Primer for Health Professionals* (No.WHO/CED/PHE/WSH/19.149). World Health Organisation.

Wright, J., Gundry, S., & Conroy, R. (2004). Household drinking water in developing countries: A systematic review of microbiological contamination between source and point-of-use. *Tropical Medicine & International Health*, *9* (1), 106-107.

Yeleliere, E., Cobbina, S. J., & Duwiejuah, A. B. (2018). Review of Ghana's water resources: the quality and management with particular focus on freshwater resources. *Applied Water Science*, *8* (3), 93.

Zin, T., Mudin, K. D., Myint, T., Naing, D. K., & Sein, T. (2013). Influencing factors for household water quality improvement in reducing diarrhoea in resource-limited areas. *WHO South-East Asia Journal of Public Health*, *2* (1), 6-11.

APPENDICES

A: Definition and measurement of variables

Variables	Code	Variable type	Unit (How it was coded)
Household main water source	Watersource	Dummy	Unimproved source=0, Improved source=1
Household use of treated water	Trewater	Dummy	No (untreated water) =0, Yes (treated water) =1,
Household sanitation facilities	Toifac	Dummy	Unimproved facility=0, Improved facility =1,
Child mother's age	Moage	Continuous	Completed age in years (15-49)
Child mother's educational level	Moedu	Categorical	No Education=0, Primary=1, SHS=2, Higher=3
Sex of the child	Chsex	Dummy	Male=0, Female=1
Age of the child	Chage	Continuous	Age in months (0-59)
Birthtype of the child	Chbirthtype	Dummy	Single=0, Twin=1
Household's wealth status	Wealthindex	Categorical	Poorest=0, Poorer=1, Middle=3, Richer=4, Richest=5
Type of area of residence	Area	Dummy	Rural=0, Urban=1
Region of residence	region	Categorical	The ten regions in Ghana

Source: Author's own compilation from literature.

B: Summary statistics of the variable used for the study

Variables	Observations	Mean	Std. Dev.	Min.	Max.
Diarrhoea	5301	0.1230	0.3285	0	1
Improved water	5301	0.8374	0.3690	0	1
Treated water	5301	0.0722	0.2416	0	1
Time to get to water source	5301	20.5641	20.8192	0	180
Improved sanitation	5301	0.1305	0.03369	0	1
Time to toilet facility	5301	19.4107	12.0833	1	120
Male child	5301	0.4785	0.4996	0	1
Child age in years	5301	1.8934	1.4100	0	4
Child age in months	5301	27.88497	17.1625	0	59
Safe disposal of stool	5301	0.29188	0.4547	0	1
Mother's age in years	5301	30.6715	6.8722	15	49
Mother's education	5301	1.13305	0.9428	0	3
Wealth index	5301	2.5240	1.3897	0	5
Single Birth type	5301	0.9576	0.2015	0	1
Rural residence	5301	0.6033	0.4892	0	1
Region	5301	5.6471	2.8371	1	10

Source: Computed from the 2014 GDHS (2019).