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Abstract

This thesis examines the interlinkages between water quality, water use, sanitation and hygiene practices, other household characteristics and health outcomes in the context of multipurpose water systems in Ghana. Household-level data newly collected for this research between 2014 and 2015 are used. In this study context, multipurpose water system is defined loosely as location or presence of water resources being used for more than one economic or domestic activity. To elicit causal relationships and impacts, the study uses both econometric analysis and a cluster randomized evaluation design. We find evidence that participation in irrigated agriculture and household head's education to secondary school level and beyond have positive and significant effects on both short run and long run nutritional status of children under eight years of age while current household per monthly income has mixed effects on child health and nutrition status. Disposal of liquid waste on the compound of the dwelling increases diarrhea risk and also leads to a reduction in nutritional status. Open defecation increases diarrhea risk. However, the effects are not uniform as they depend on the choice of child health and nutrition indicators.

Secondly, the thesis evaluates the impacts of a household water quality testing and information experiment on water behaviors, using a randomized control trial. In 2014, a group of 512 households relying on unimproved water, sanitation and hygiene practices in the Greater Accra region of Ghana were randomly selected to participate in the intervention on water quality self-testing and to receive water quality improvement messages (information). The results suggest that the household water quality testing and information experiment increase the choice of improved water sources and other safe water behaviors. The school children intervention group is more effective in the delivery of water quality information, thereby making a strong case of using school children as “agents of change” in improving safe water behaviors.

The third component of the thesis is on the impacts of household water quality testing and information experiment on health outcomes, and on sanitation and hygiene-related risk-mitigating behaviors, using a cluster-randomized controlled design and the estimation strategy already described above. The results show that there is high household willingness to participate in this intervention on water quality self-testing. About seven months after taking part in the intervention, the study, however, finds little impacts on health outcomes, and on sanitation and hygiene-related risk-mitigating behaviors, based on the treatment assignment.

Zusammenfassung

Diese Arbeit untersucht die Zusammenhänge zwischen Wasserqualität, Wasserverbrauch, der Sanitärversorgung, Hygienepraktiken, anderen Haushaltsmerkmalen und ihre Auswirkung auf die Gesundheit im Zusammenhang mit Mehrzweck-Wassersystemen in Ghana. Es werden Haushaltsdaten verwendet, die für diese Forschung zwischen 2014 und 2015 neu erhoben wurden. In diesem Studienkontext wird das Mehrzweckwassersystem lose definiert als Standort oder Vorhandensein von Wasserressourcen, die für mehr als eine wirtschaftliche oder häusliche Tätigkeit genutzt werden. Um Kausalbeziehungen und -effekten festzustellen, verwendet die Studie sowohl eine ökonometrische Analyse als auch ein Cluster-randomisiertes Evaluationsdesign. Wir finden Beweise, dass die Teilnahme an der bewässerten Landwirtschaft und die Ausbildung an einer Sekundarschule der einzelnen Mitglieder eines Haushalts positive und signifikante Auswirkungen auf den kurz-und langfristigen Ernährungszustand von Kindern unter acht Jahren hat, während das aktuell verfügbare, monatliche Einkommen eines Haushalts gemischte Auswirkungen auf die Gesundheit von Kindern und ihren Ernährungszustand hat. Die Entsorgung von flüssigen Abfällen auf dem Grundstück der Wohnung erhöht das Durchfallrisiko und führt auch zu einer Verminderung des Ernährungszustands. Offene Defäkation erhöht das Durchfallrisiko. Allerdings sind die Effekte nicht einheitlich, da sie von der Wahl der Indikatoren „Kindergesundheit“ und „Ernährung“ abhängen.

Zweitens bewertet die Arbeit die Auswirkungen eines Wasserqualitätstests in einem Haushalt Informationen Experiment auf Verhaltensweisen bei der Wassernutzung, mit einem randomisierten Kontrollversuch. Im Jahr 2014 wurde eine Gruppe von 512 Haushalten, die sich auf nicht verbesserte Wasser-, Hygiene- und Hygienepraktiken in der Region „Greater Accra“ in Ghana stützten, nach dem Zufallsprinzip ausgewählt, um an der Intervention für Wasserqualität-Selbsttests teilzunehmen und Informationen zur Verbesserung der Wasserqualität zu erhalten. Die Ergebnisse deuten darauf hin, dass Selbsttests zur Wasserqualität in Haushalten und Informationsexperimente die Anzahl der Entscheidungen für verbesserte Wasserquellen und für andere Formen des sicheren Umgangs mit Wasser erhöhen. Die Schulkinder-Interventionsgruppe ist effektiver bei der Bereitstellung von Wasserqualitätsinformationen, was starke Argumente dafür liefert, Schulkinder als "Agenten des Wandels" bei der Verbesserung des sicheren Wasserverhaltens heranzuziehen.

Der dritte Teil der Arbeit beschäftigt sich mit den Auswirkungen von Wasserqualitätstests und Informationsexperimenten auf die Gesundheitsfolgen sowie auf sanitäre und hygienerelevante, risikomindernde Verhaltensweisen unter Verwendung eines Cluster-randomisierten, kontrollierten Designs und der bereits beschriebenen Schätzstrategie. Die Ergebnisse zeigen, dass es eine hohe Bereitschaft der Haushalte gibt, an der Vermittlung von Kenntnissen zur Selbstprüfung von Wasserqualität teilzunehmen. Etwa sieben Monate nach der Teilnahme an der Vermittlung findet die Studie jedoch nur geringe Auswirkungen auf die gesundheitlichen Folgen sowie auf sanitäre und hygienerelevante, risikomindernde Verhaltensweisen, basierend auf der Behandlungsaufgabe.

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Abbreviations and Acronyms

2SLS	Two Stage Least Squares
ADB	African Development Bank
AG-WATSAN	Agriculture, and Water and Sanitation
BECE	Basic Education Certificate Examination
BIVs	Biologically Implausible Values
BPA	Bui Power Authority
CBT	Compartment Bag Test
CFRs	Case Fatality Rates
DiD	Differences-in-Differences
E. coli	Escherichia coli
FASDEP	Food and Agriculture Sector Development Policy
GBD	Global Burden of Disease
GDP	Gross Domestic Product
GES	Ghana Education Service
GIDA	Ghana Irrigation Development Authority
GIDP	Ghana Irrigation Development Policy
GLSS	Ghana Living Standard Survey
GSS	Ghana Statistical Service
ISSER	Institute of Statistical, Social and Economic Research
ITT	Intention-to-Treat
IV	Instrumental Variable
IWRM	Integrated Water Resources Management
JMP	Joint Monitoring Program
KIS	Kpong Irrigation Scheme
LATE	Local Average Treatment Effect
METASIP	Medium Term Agriculture Sector Investment Plan
MoFA	Ministry of Food and Agriculture
MPN	Most Probable Number
MUS	Multiple-use Water Services
MW	Megawatts
NHIS	National Health Insurance Scheme
NMIMR	Noguchi Memorial Institute for Medical Research
OLS	Ordinary Least Squares
PHC	Population and Housing Census
POS	Point of Source
POU	Point of Use

PPP	Purchasing Power Parity
PSM	Propensity Score Matching
RCT	Randomized Controlled Trial
SDGs	Sustainable Development Goals
SFIP	Small Farms Irrigation Project
SHEP	School Health Education Program
SSIDP	Small Scale Irrigation Development Project
UN	United Nations
UNICEF	United Nations Children`s Fund
US	United States
USA	United States of America
WASH	Water, Sanitation and Hygiene
WATSAN	Water and Sanitation
WHO	World Health Organization
WRC	Water Resources Commission
ZEF	Center for Development Research

Chapter 1. Introduction

1.1 Background

In recent times, water, sanitation and hygiene (WASH) practices have become an integral component of worldwide public health, particularly among children under-five years of age in developing countries, due to their vulnerability to diarrhea, malaria, undernutrition and their combinations. As of 2012, approximately 700 million people around the world relied on unsafe drinking water while about 2.5 billion people lacked improved sanitation facilities (World Health Organization (WHO), 2014). Mounting evidence shows that sub-Saharan Africa and rural areas have the least coverage in terms of improved water and sanitation - an indication of region and location differences in the use of unimproved water and sanitation.

Availability of quality water is essential for the general well-being of every human society. This is based on one of the most popular adages on water such as "water is life". In Ghana, two types of household water exist (1) drinking water and (2) water for general use (such as cooking, washing, bathing, among others). According to Ghana Statistical Service (GSS) (2014), based on the sixth Ghana Living Standard Survey (GLSS 6), about 28.9 percent of households have access to pipe-borne water as the main source of drinking water, bottled/sachet water is used by 28.4 percent of the households, with 32.3 percent of the households using water from wells as the main source of drinking water while about 9 percent of the households use water from natural sources (including river, streams, spring, rain water, among others). Differences exist in terms of water availability for general use when compared with drinking water sources. About 42 percent of the households use pipe-borne water as the main source of water for general use, with 40.4 percent of the households using wells for the same purpose, while natural sources account for about 12.1 percent of all general water use among households in Ghana (GSS, 2014).

Globally, fecal contamination of drinking water sources is pervasive and also affects practically all drinking water sources including pipe-borne water into the premises. Fecal contamination of drinking water sources affects more than one-fourth of the global population. Worldwide, approximately 1.1 billion people consume drinking water with moderate risk (>10 *E. coli per 100mL*), while about one in ten of improved drinking water sources suffer from high risk of fecal contamination (at least 100 *E. coli per 100mL*). Furthermore, fecal contamination of drinking water sources is widespread in rural areas and Africa compared with urban and other regions respectively - indicating an uneven situation (Bain *et al*., 2014). In Ghana, arsenic contamination of both water sources and household stored water is generally low while fecal contamination (*E. coli*) is moderately high. As part of the GLSS 6, water sample analyses show that about 43.5 percent of sampled water sources and 62.1 percent of household stored water contained *E. coli* (an indicator of fecal contamination). About 8.4 percent of all water sources and 17.6 percent of household stored water suffer from very high risk of *E. coli* contamination (i.e. *E. coli* >100 cfu/100mL). The increase in fecal contamination level between water sources and household stored water represent relatively low or poor water handling techniques and management. About 8.6 percent of the water sources and 5.6 percent of household stored water contained arsenic level above the Ghana standard of at most 10 parts per billion (ppb). The level of fecal and arsenic contamination also depends on the type of water source and location (rural vs. urban) or region. Bottled/sachet water contains the least levels of arsenic and *E. coli* (or fecal contamination), followed by improved water sources while unimproved water sources have the highest level of contamination (GSS, 2014).

Significant milestones have been achieved in terms of reduction of WASH-related morbidity and mortality as a result of safe stool disposal, handwashing with soap, improved drinking and general purpose water sources and improved sanitation. However, WASH-related morbidity and mortality remain as one of the leading causes of diseases and deaths in children below the ages of five in many low- and middle-income countries. Furthermore, in relative or percentage terms the latest estimates for most WASH-related morbidity and mortality shows a decreasing trend, but in absolute terms, the figures are large to warrant serious attention in terms of studies and resources. The Global Burden of Disease (GBD) study 2015 shows that diarrhea and malaria in 2013 accounted for 1.3 million and 854,600 deaths worldwide, respectively. The same study shows that from 2000 to 2013 diarrheal deaths decreased by about 31.1 percent from 1.8 million to 1.3 million while between 1990 and 2013, mortality from malaria decreased by 4.4 percent. According to Walker *et al*., (2012), diarrhea incidence decrease from 3.4 episode/child year in 1990 to 2.9 episode/child year in 2010. In another study Walker *et al*., (2013) estimated that in 2010 the global diarrhea episodes were 1.7 billion. Globally, about two percent of all diarrhea diseases develop from mild cases to severe cases. The mortality rate from diarrheal diseases is high among children under 2 years of age (72% of deaths). Diarrhea incidence is more prevalent in boys than girls. The African region where Ghana is located has the highest rate of diarrhea incidence, diarrhea mortality, and total severe cases (Walker *et al*., (2013)). Therefore, it is not surprising that malaria and diarrheal diseases are among the five main causes of under-five mortality worldwide.

The continuous increase, in absolute terms, of WASH-related mortality and morbidity is due to several reasons, but primarily among them the increase in population and the slower rate of reductions of these diseases in the high endemic regions especially sub-Saharan Africa. Furthermore, mortality in children under five years of age as result of undernutrition presents an additional challenge to current efforts in global public health. In 2011, stunted growth affected about 165 million children below the ages of five years while wasting affected about 52 million children within the same age bracket. In addition, in 2011, undernutrition caused about 3.1 million deaths among children (representing about 45 percent of worldwide deaths of children). Stunting is higher in sub-Saharan Africa than other regions of the world (Black *et al*., 2013).

The relationship between WASH, diarrhea morbidity and undernutrition is complex, but it is widely known that a poor WASH environment leads to a higher rate of diarrheal morbidity and mortality, while the nutrition status of children is affected by diarrheal episodes and the WASH environment. Therefore, the interface between poor WASH, diarrhea, and undernutrition present a credible threat to current efforts in poverty reduction, human capital formation, and productivity. This vicious cycle is more prevalent in sub-Saharan Africa. The world stands to benefit enormously in terms of poverty reduction, human capital formation, and productivity through increased access to improved water, sanitation and hygiene practices, reduced diarrheal mortality and morbidity, and decreased malnutrition. For example, reduction in diarrheal morbidity and mortality plays a leading role in the improvement of life expectancy. The Global Burden of Disease (GBD) study 2015 indicates that life expectancy increased by 2.2 years between 1990 to 2013 due to lower diarrheal diseases. A large literature exists which shows the association of water, sanitation and hygiene and health outcomes. Improved WASH is linked to lower rates of diarrheal diseases (Norman *et al*., 2010; Fink *et al*., 2011) and stunting (Fink *et al*., 2011). Undernutrition represents one of the many risk factors associated with diarrhea mortality and morbidity (Walker *et al*., (2013); Walker *et al.,* (2012)). Some studies also show the interlinkages between nutrition and WASH on educational outcomes. Poor WASH affects school attendance and academic performance of school-age children (UNICEF, 2006; Dreibelbis *et al*., (2013)). Malnutrition could lead to poor academic performance and school absenteeism (Brown *et al*., 2013).

While diarrhea and other WASH-related diseases do not lead to high death rates or case fatality rates (CFRs) associated with other diseases such as Ebola or HIV/AIDS, they constitute a major threat due to their high frequency of occurrence and long term effects on child growth, productivity, and human capital formation. Persistent occurrences and longer duration of WASH-related diseases (for instance diarrhea) could lead to poor child growth and development in terms of stunting, wasting (Gupta, 2014; Brown *et al*., 2013; Checkley *et al*., 2008; Guerrant *et al*., 2013) and low education outcomes (e.g. school absenteeism) and low cognitive outcomes (e.g. poor academic performance) (Brown *et al*., 2013; Lorntz *et al*., 2006; Kvestad *et al*., 2015; Guerrant *et al*., 2013), possibly also indirectly through other pathways, including micronutrient and macronutrient deficiencies. Infectious diseases and diarrhea are among the main causes of stunting and wasting in children in poor resource countries (UNICEF, 2006; Brown *et al*., 2013). Improved WASH environment could potentially interrupt disease transmission, creating unintended health and educational benefits. An important aspect of improved WASH in developing countries is that it is economically beneficial or cost-effective in terms of investing resources. According to Hutton *et al*., (2007), an investment of US$1 in water and sanitation improvements generates a return of US$ 5 to US$ 46.

In recent years, considerable resources and studies have been dedicated to understanding the influence of social interventions, socioeconomic characteristics, water, sanitation and hygiene behaviors of parents and households on health (diarrhea incidence and prevalence), mortality (or child survival), and nutrition (wasting and stunting). Studies by Aiello and Larson (2002), Gamper-Rabindran *et al*., (2010), Lee *et al*., (1997) and (Zhang, 2012) are some of the examples of the growing literature showing the effects of social programs, WASH, and parental characteristics on health outcomes (including child health) in low- and- middle income settings. From these studies, some analyses the provision of improved WASH interventions (for instance provision of piped water) on health outcomes such as self-reported health status, the incidence of illness, weight-for-height, height-for-age, height, and infections. Other studies have also shown the importance of environmental factors and/or household characteristics as the determinants of health outcomes.

Showing the direct and indirect linkages between WASH and health and nutrition outcomes is more complex with uncertain/unpredictable results. In some of the previous studies, the effects of WASH on health outcomes are direct and in other studies, they are not. There is large literature indicating the association of improved WASH to decrease in diarrhea risks (Wolf *et al.,* 2014). Improved drinking water quality increases weight-for-height and height, and also decreases the incidence of illness in both adults and children (Zhang, 2012). A study by Gamper-Rabindran *et al*., (2010) shows that the provision of piped water decreases death of infants in Brazil. Aiello and Larson (2002) showed that adequate personal and community (environmental) hygiene has a positive effect on infections. According to Van der Hoek *et al.,* (2002), provision of an adequate amount of water for household domestic use and the use of toilet facilities lead to decrease in diarrhea and malnutrition (stunting) in Pakistan. In addition, children in households with larger water storage capacity have a lower incidence of diarrhea and stunting. However, a study by Lee *et al*., (1997), showed that improvement in water sources or sanitation facilities does not significantly affect child survival.

There are several studies showing the determinants of health outcomes using individual, household and community variables. However, studies on the effects of multipurpose water systems on health outcomes are rare. More so, those on the synergetic effects or nexus or tradeoffs between multipurpose water systems, and water, sanitation and hygiene practices on health outcomes are uncommon. The study argues that the combined effects of multipurpose water systems together with WASH and other household covariates will better explain health outcomes in Ghana. The presence of multipurpose water systems affects health outcomes in diverse ways including household’s participation in irrigated agriculture and fishing. According to WHO (2013), food contamination through irrigation water is among the causes of diarrhea. Irrigation fields and water bodies serve as breeding grounds for mosquitoes, which lead to high incidence of malaria in those areas (Fobil *et al*., 2012). Besides the negative externalities are also the positive aspects of irrigated agriculture. Involvement in irrigation activities could enhance household income and availability of food all year round. This has the potential of counterbalancing the negative health effects from irrigation water sources and irrigated agriculture. Irrigation canals could also serve as additional source of water supply thereby improving water security and demand.

WHO (2013) indicated that diarrhea morbidity could be caused by eating seafood and fish from contaminated water sources. Furthermore, the spatial dimension based on geographic information systems of the location of surface water bodies (including fishing waters and irrigation water sources) could explain the mortality from infectious diseases (including diarrhea) in urban areas (Fobil *et al*., 2012). Open defecation around water bodies is among the causes of diarrhea and malaria in many developing countries. However, household engagement in fishing and communities with fishing waters could derive positive benefits in terms of availability of nutritious food through consumption of fish and other seafood, which could offset the negative health risks/effects in residing in fishing localities and actual participation in fishing.

This study shows that the presence of multipurpose water systems improves or child health outcomes. The linkages between multipurpose water systems and health outcomes could be two sided: on the positive side multipurpose water systems and its direct benefits of irrigated agriculture and fishing could boost the income generating capacities of households, thereby leading to improved health outcomes (i.e. through income effects). On the negative side, water contamination, being exposed to open fresh water bodies, and reliance on unimproved water sources such as rivers or canals could become a major health risk for households residing in areas with multipurpose water systems. This current study considers multipurpose water systems, and other individual and household variables including socioeconomic characteristics and investigates how these factors interplay in affecting health outcomes, particularly child health and nutrition status in southern Ghana. Up-to-date evidence on the interactions between multipurpose water systems, water quality, sanitation, and hygiene is needed for the development of health policies at global, regional, national and local (district) levels. Then in using the settings of multipurpose water systems, we study the impacts of household water quality testing and information experiment on water, sanitation and hygiene behaviors, and on health outcomes. The experiment is a multi-arm study based on the concept or idea that intra-household resource allocation or decision making matters when it comes to the dissemination of water quality information.

This study is related to existing literature. First, there is now a lot of literature on factors affecting household health and nutritional outcomes. Studies that incorporate irrigation water into the determinants of household health and nutritional outcomes date back to Van Der Hoek *et al*. (1999) and Van Der Hoek *et al.* (2001). Van Der Hoek *et al.* (2001) consider the health implications of using irrigation water as the source of drinking water. Their study shows that good quality drinking water plays a complementary role to increased water quantity and the availability of toilet facility in reducing diarrhea. This study is also related to many other studies that use models in which water from irrigation facilities acts as important determinants of household health and nutritional outcomes. Jensen *et al*., (2001) study the shortfalls in the guidelines in assessing irrigation water quality. From multiple use perspective, their study shows that the guidelines were inadequate in addressing the water quality issues, due to its application to mainly agricultural purposes (crops), leaving out other essential non-agricultural users. Meinzen-Dick and Van Der Hoek (2001) illustrated that irrigation water serves multiple uses thereby being crucial to household income, health, and nutritional outcomes. In another study, Van Der Hoek *et al*., (2002) recommended an integrated management of irrigation water, since the increase in water quantity through irrigation water is associated with less diarrhea and malnutrition. The main contribution of this study in relation to irrigated agriculture is that household's participation in irrigated agriculture affects health and nutrition outcomes.

Second, previous studies on health and nutritional outcomes neglected the implications of household's participation in fishing. The previous literature that comes close to this study is related to the consumption of certain fish species and the occurrences of diarrhea. Diarrhea morbidity is linked to the consumption of rudderfish (Shadbolt *et al*., (2002)) and butterfish (Gregory, 2002). This study contributes to the literature by studying the effects of household's participation in fishing on health and nutrition outcomes.

Third, previous studies did not apply the systems perspective in addressing the WASH-related issues and multipurpose water systems on one hand, and health outcomes on the other hand. In this study, the system perspective is applied in analyzing the interlinkages between multipurpose water systems, WASH and health outcomes. The study begins with the analysis of WASH and multipurpose water systems and their effects on health outcomes. This aspect represents the analysis of the key factors influencing health outcomes by applying standard econometric techniques such as random effects model in a panel data analysis. This section is related to the growing literature on the environment and household characteristics as determinants of health and nutritional outcomes. Finally, the study moves a step further by analyzing changes in health outcomes and WASH behaviors after the participation of households in a water quality testing and information experiment. This is undertaken through a cluster-randomized evaluation design.

1.2 Research Objectives

The main objective of this study is to analyze the effects of water quality, multipurpose water systems, sanitation, and hygiene on health and nutrition outcomes in southern Ghana. In this geographical context, the specific objectives of the study are as follows:

1. To examine the synergetic effects or nexus or tradeoffs between multipurpose water systems, and water, sanitation and hygiene practices on health and nutrition outcomes.

2. To estimate the impacts of household water quality testing and information on safe water behaviors.

3. To estimate the impacts of household water quality testing and information on health outcomes, and sanitation and hygiene-related risk-mitigating behaviors.

1.3 Expected Value Addition

The interface between water quality and quantity, sanitation, hygiene and multipurpose water systems on health and nutritional outcomes makes it important to study its determinants. In this respect, the environmental and household factors influencing health and nutritional outcomes will provide additional information to researchers and policy makers in public health. Using a random effects model in a panel data analysis presents an opportunity in understanding the time invariant dimension to these factors. Multipurpose water systems including irrigated agriculture and fishing are under-researched compared to other environmental factors affecting health and nutritional outcomes. This study helps fill that gap in the literature.

The application of cluster-randomized evaluation design in analyzing the impacts of the household water quality testing and information experiment on health outcomes and WASH behavior changes makes several important contributions to literature. The study applies multi-arm randomized trials to estimate the impacts of delivering water quality and water handling information through different household members. Previous studies (Brown *et* al., 2014; Madajewicz *et al*., 2007; Hamoudi *et al*., 2012; Jalan and Somanthan, 2008) conducted "two-study-arm study" (i.e. either control or treatment), with no or little mention of the channels for the delivery of such water quality information. This study estimates the heterogeneous impacts by analyzing the most effective channel (male vs. female, and school children vs. adult household members) in the delivery of water quality information to the households. Studies in which water quality information is disseminated to randomly selected households without addressing intra-household resource allocation or decision-making processes miss first the potential learning effects of household water quality self-testing and self-recording of results, and second also miss the identification of the most effective channels for the delivery of such information to the treatment groups.

In addition, the study uses water testing toolkits (Aquagenx's Compartment Bag Test (CBT)) that quantify the level of *E. coli* (based on the most probable number (MPN)) present in water samples. This is an improvement on previous studies (Brown *et al*., 2014; Madajewicz *et al*., 2007; Hamoudi *et al*., 2012; Jalan and Somanthan, 2008) that used presence or absence test kits.

The "formal" household water quality testing fits into the Sustainable Development Goals (SDGs) and especially targets on improvement in water quality. Therefore, this study intends to contribute on the relevance of including water quality monitoring, especially testing for microbial properties of water at the household, community and basic school levels, in the United Nations (UN) Post-2015 Sustainable Development Goals (SDGs). Furthermore, WHO recommends water quality testing at least twice per annum at the source (and by extension the household level). This study is thus helping to determine the relevance of such guidelines.

1.4 Structure of Thesis

The thesis is organized as follows. Chapter 2 analyzes the synergetic effects or nexus or tradeoffs between multipurpose water systems, and water, sanitation and hygiene practices on health and nutrition outcomes. In chapter 3, the study analyzes the impacts of the household water quality testing and information experiment on safe water behaviors. In chapter 4, the study focuses on the impacts of the experiment on health outcomes, and on sanitation and hygiene-related risk-mitigating behaviors. Chapter 5 concludes by summarizing the main results of the thesis and by discussing their policy implications.

Chapter 2. Understanding the Interactions between Multipurpose Water Systems, Water and Sanitation, and Child Health and Nutrition: Evidence from Southern Ghana

2.1 Introduction and Problem Statement

The Republic of Ghana (hereafter Ghana), a lower middle-income country based on World Bank income classification, in recent times has been an economic success in sub-Saharan Africa with an average of 7.6 percent annual growth rate of gross domestic product (GDP) from 2007 to 2014. However, the annual growth rate of the GDP has not been even for the period of 2007 to 2014, with the figures oscillating from 4.3 percent in 2007 to 14 percent in 2011 and then back to 4 percent in 2014 (Ghana Statistical Service (GSS), 2014a and 2015). While moderate economic success has been achieved, as to whether it has led to improved health care delivery remains to be seen. For instance, in 2013 total health expenditure as a share of the GDP was 5.4 percent while per capita total expenditure on health in purchasing power parity (PPP) terms stood at US 214 dollars. For the period of 2007 to 2014, per capita government expenditure on health, in PPP terms, increased from USD 95 to USD 130 (WHO, 2015a).

Ghana, after 60 years of self-rule, faces challenges with health care delivery and malnutrition. This perennial problem of malnutrition and poor health care delivery among children is also a common trend in sub-Saharan Africa. It needs to be mentioned that Ghana’s indicators on health and nutrition are in most cases better than that of the sub-Saharan African region. In 2013, Ghana’s under-five mortality rate per 1000 live births was 78. In addition, malaria and diarrhea respectively caused 20 percent and 8 percent of the total deaths among children under-five years of age (WHO, 2015b). Estimates show that in Ghana, stunting, underweight and wasting respectively affect 28, 14 and 9 percent of children under-five years of age (WHO, undated; and UNICEF, 2009). While these estimates on child health and nutrition seem better compared to other countries in sub-Saharan Africa, the figures themselves are large enough to be given serious consideration. Using a household panel data collected in the Greater Accra region of Ghana between 2014 and 2015, we study the determinants of health and nutritional status of children in areas with multipurpose water systems.

There is inconclusive evidence on the determinants of child health and nutrition status, especially on the role of multipurpose water systems, and water, sanitation and hygiene and other household characteristics. The study contributes to filling this gap in the literature. There is a large body of literature on the effects of individual, household and community characteristics on child health and nutrition status through the application of various econometric or regression frameworks. Few studies in the anthropometry literature, however, have analyzed the interactions between the multipurpose water systems, and water, sanitation and hygiene practices, and other household characteristics as the determinants of child health and nutrition status in resource poor settings. Ignoring these effects or interactions do not adequately account for the multidimensional nature or complexities of the determinants of child health and nutrition status in many developing countries. For example, according to van der Hoek *et al*., (2002), households with large water storage and toilet facilities reduce the risk of stunting in children in southern Punjab, Pakistan. In Pal (1999), female literacy rate increases the nutritional status of boys at the expense of girls while improvement in household current per capita income improves the nutritional status of both boys and girls, although the effect is larger for boys than girls. The study concluded that improvement in literacy rate and income leads to higher nutritional status of boys than girls in rural India. Thomas and Strauss (1992) consider the impact of prices, infrastructure, and household characteristics on the height of children in Brazil, finding that access to modern sewerage, pipe-borne water and electricity positively affect child height while the increase in prices of sugar and milk negatively affect child height. However, mothers' education to the elementary level is able to neutralize the negative impacts of prices on child height. Relatedly Thomas *et al*., (1990) examine the role of household characteristics on child survival and height for age in Brazil. They show that education or literacy rate and height of parents positively affect child survival and height for age. In addition, household income statistically and significantly affects child survival but not child height, with the latter being dependent on the choice of instrumental variables for income. In another study Thomas *et al*., (1996) find that availability of basic health services positively affects child health while increased prices of food negatively affect child health in Côte d'Ivoire. Ayllon and Ferreira-Batista (2015) use instrumental variable estimation approach and find that single mother parenthood negatively affects children height-for-age z-score compared to children being raised by both parents. Schmidt (2014) argues that promotion of sanitation and hygiene should be an integral part of current efforts in averting stunting in children. In a cohort study, Checkley *et al*., (2004) found that height of children in households with inadequate water, sanitation, and water storage was one centimeter (1 cm) shorter than their counterparts with the best conditions were. Tharakan and Suchindran (1999) found that nutritional status of children in Botswana such as stunting, wasting and underweight are influenced by a wide range of individual, biological, cultural, household and socio-economic factors.

Similarly, many studies (especially in the medical literature) have shown evidence that individual, household and community characteristics affect the incidence of diarrhea among children in developing countries. To the best of our knowledge studies that consider the interactions effects between multipurpose water systems, and water, sanitation and hygiene practices, and other household characteristics on diarrhea incidence are rare. For example, Masangwi *et al*., (2009) indicate that children in households without toilet facilities were more likely to suffer from diarrhea incidence while children in households with own tap connection and improved handwashing facilities such as running tap water or own basin were less likely to suffer from diarrhea incidence. In another study, van der Hoek *et al*., (2002) finds that households with large water storage and toilet facilities reduce the risk of diarrhea in children in southern Punjab, Pakistan. Kandala *et al*., (2006) show that maternal education reduces the occurrences of diarrhea morbidity in Malawi. Also, there is a nonlinear relationship between diarrhea and child's age (see also Mihrete *et al*., 2014). Ssenyonga *et al*., (2009) find that children younger than two years of age, residence in Northern and Eastern regions, and fever in past two weeks preceding the study were positively associated with diarrhea occurrences while maternal education to secondary school level and improved water sources such as protected well or borehole reduce diarrhea morbidity in Uganda. Jalan and Ravallion (2003) use propensity score matching (PSM) to study the effects of piped water on diarrhea for children in rural India and find that under-five-year-old children in households with piped water compared to their counterparts have lower rates of prevalence and shorter duration of diarrhea morbidity. Although, the effects are lower for children with mothers having low literacy rate. In a meta-analysis, Norman *et al*., (2010) find that proper sewage systems are associated with about 30 percent reduction in diarrhea incidence. Other studies show that the use of surface water and poor hygiene increases diarrhea morbidity (Tumwine *et al*., 2002). In a cohort study, Checkley *et al*., (2004) analyzes the effect of water and sanitation on child health in peri-urban Peru and find that children in households with a poor water source, sanitation, and water storage had about 54 percent more diarrhea morbidity compared to their counterparts with the best conditions. Furthermore, children in households with small storage facilities had 28 percent more diarrhea cases than their counterparts in households with large storage facilities.

Aside from studies using econometric strategy or regression frameworks, those applying experimental economic approaches have also shown that improving child health and nutrition status in many developing countries is far more complex. For instance, experimental economic analyses on the linkage between water quality and quantity interventions on child health and nutrition status have not achieved uniform/even results. In Kremer *et al*., (2011), spring protection in rural Kenya leads to a reduction in diarrhea incidence for children under three years of age but no improvement in anthropometric outcomes such as weight and BMI. Devoto *et al*., (2012) study the impacts of facilitating household access to credit in private pipe water connection in urban Morocco. The study finds no impacts on reduction of diarrhea incidence for children under-seven years of age. Günther and Schipper (2013) study the impacts of safe water storage and transport containers on health outcomes in Benin. While there was a statistically significant reduction in diarrhea incidence for individuals above five years of age, there were no impacts for children under-five years of age.

The main contribution of this study is that the connection between different uses of water, and water, sanitation and hygiene practices, and other household characteristics are important explanatory variables or determinants of child health and nutrition outcomes in resource poor settings. The presence of multipurpose water systems, and particularly household participation in irrigated agriculture and fishing either could positively or negatively affect child health and nutrition outcomes. However, we test the hypothesis that participation in irrigated agriculture and fishing positively affect child health and nutrition outcomes. On the positive side, the presence of multipurpose water systems serving both domestic and economic purposes could lead to improved child health and nutrition outcomes through increased household income and access to nutritious diets (for example fish, vegetables, etc.). On the contrary, being located in multipurpose water systems and its associated benefits of irrigated agriculture and fishing could lead to negative health and nutrition outcomes, through increased contamination in drinking and general purpose water sources leading to high incidence of diarrhea. Children and household members being exposed to open water body either for fishing or irrigated agriculture may present an additional health risk. Furthermore, fresh water sources may serve as breeding grounds for mosquitoes, which could lead to high incidence of malaria. Likewise, there may be no statistically significant effect if the positive and negative effects balance each other.

Child health and nutrition status is measured using various indicators. In the literature on child health and nutrition, anthropometric outcomes such as height, weight, weight for height, and body mass index (BMI) have largely been used (Kremer *et al*., 2011; Pal, 1999; Thomas *et al*., 1995; Thomas *et al*., 1990; Thomas *et al*., 1992; Lee *et al*., 1997). Furthermore, height and weight are used to measure long run nutritional status while weight for height represents the short run nutritional status of children (Linnemayr *et al*., 2008; Strauss, 1990; Pal, 1999). The health and nutrition outcomes are usually analyzed within the framework of Becker (1965), Becker and Lewis (1973), and Becker (1981) models on household decisions on the trade-off between child quality and quantity. Not deviating from these standard models, we rather expand the analysis to include diarrhea incidence in the past four weeks as one of the indicators of child health. We estimate random effects model in a panel data analysis in analyzing the determinants of child health and nutrition indicators. Few studies in the anthropometry literature have estimated random effects model in a panel data analysis.

Child health and nutrition outcomes have being analyzed for different age categories: under-three years of age (Kremer *et al*., 2011), under-five years of age (Pal, 1999; Jalan and Ravallion, 2003), under-seven years of age (Devoto *et al*., 2012; Senauer and Garcia, 1991); under-eight years of age (Thomas *et al*., 1992; Thomas *et al*., 1990), and under-12 years of age (Thomas *et al*., 1996). The study estimates the determinants of child health and nutrition outcomes for children under-eight years of age as measured by diarrhea incidence in the past four weeks, height, weight, weight for height and body mass index. This study adds to the literature on child health and nutrition in that it analyzes the synergetic effects of multipurpose water systems, and water, sanitation and hygiene, and other household characteristics and also makes use of wide range of indicators of child health and nutrition status.

This study addresses three research questions: (i) What are the effects of water, sanitation and hygiene (WASH) practices on child health and nutrition outcomes? (ii) What are the effects of multipurpose water systems particularly in terms of participation in irrigated agriculture and fishing on child health and nutrition outcomes? (iii) What are the effects of other household characteristics on child health and nutrition outcomes? These research questions are essential in understanding the complexities of the determinants of child health and nutrition outcomes in resource poor settings. The outline of this study is as follows. Section 2.2 discusses multipurpose water systems in Ghana. Section 2.3 outlines the methodology and data sources. The analytical framework including models and empirical issues are addressed. Section 2.4 presents the results and discussion. Finally, section 2.5 concludes the study.

2.2 Multipurpose Water Systems in Ghana

Diverse typologies of multiuse or multipurpose water systems/services in literature have been noted, which can be classified into two broad approaches, namely; (1) conventional or traditional approach and (2) systematic or holistic approach. Multipurpose water systems viewed in terms of the conventional or traditional approach is based on the notion that water resources historically have had multiple uses. In other words, based on the conventional or traditional approach water resources for a long time ago have had more than one use. For instance, rivers or lakes have traditionally or historically been simultaneously used for transportation, swimming, fishing, domestic purposes, among others.

The systematic approach views multiuse water systems as an innovational means of addressing the divergent needs of water users. Multipurpose or multiple-use water systems has been developed recently as systematic or holistic approach in addressing efficient allocation of water resources between domestic use (for example cooking, drinking, bathing, etc.) and productive or agricultural use (for example irrigated agriculture, fishery, livestock rearing, etc.) (Practical Action, 2015; Multiple-use Water Services (MUS) Group, 2013). This relatively new approach to integrated water resource management gained traction, especially, in the late 1990s and early 2000s and has been successfully implemented in several countries including Nepal, Ethiopia, Bangladesh, and Honduras.

In recent times, multipurpose water systems instead of single-use water systems have been advocated for by development agencies including African Development Bank (ADB). This approach takes into consideration the needs of different water users in planning and implementation of investment in water resources, thereby having the best chance of making wider impacts on household welfare. This approach works within the larger framework of balancing trade-offs in the nexus between agriculture, water and sanitation, energy and food/income security.

In most cases implementing multipurpose water systems as a holistic or systematic approach requires investment in new technologies or a reallocation of investment resources. For example, gravity method or use of pipe water for irrigated agriculture and domestic purposes involves capital investment in transforming existing single use water services/systems into multiple use water systems. In other cases, water users faced with difficulty in using single-use water systems for other purposes have to improvise their own means using available local technologies in transforming the existing system.

Multiple use water systems/services contribute to the Ghanaian economy in diverse ways especially through agriculture, fishery, transportation, tourism, and energy. In Ghana, the cultivated land under irrigation is very low and this has to be addressed in order for the agricultural sector to fulfill its full potential. According to Ministry of Food and Agriculture (MoFA) (2010), agriculture land accounts for 57.1 percent of the total land area of Ghana. About 53.6 percent of agricultural land is under cultivation while only 0.2 percent of the land area under cultivation is used for irrigation. In total, about 8 percent of the land mass of Ghana is under inland waters including lakes, rivers, and streams. In another study Namara *et al*., (2010) indicate that Ghana is endowed with water resources with overall water redrawal as a share of overall renewable water resources been 1.8 percent.

The Bui Dam in the Brong Ahafo region of Ghana, whose construction began in 2007 and was completed in 2013, is a multipurpose dam with capacity for energy (power) generation, irrigated agriculture, domestic water use, fishery, animal husbandry and tourism. According to Bui Power Authority (BPA) (2012), the Bui hydroelectric project (dam) has an installed capacity of 400 megawatts (MW) and a potentially irrigable land of about 30,000 hectares (ha). Furthermore, the discovery of oil and gas in commercial quantities in 2007 in offshore of Cape Three Points (i.e. in the sea) in the Western region of Ghana has been a major boost to the Ghanaian economy. In 2014, oil contributed about GHS 7,793 million (7.2%) to the GDP while fishing, electricity, and water and sewerage contributed GHS 1,279 million (1.2%), GHS 443 million (0.4%) and GHS 576 million (0.5%) respectively to Ghana’s GDP (GSS, 2015). In Ghana, agriculture/fishery constitutes the largest employment sector accounting for about 44.3 percent of the total economically active population. In rural areas of Ghana, agriculture/fishery employs about 70.7 percent of the workforce (GSS, 2014b). Water resources are an important source of livelihood in our study sites in Shai-Osudoku district and Ga South Municipal of Ghana’s Greater Accra region. In the baseline survey, approximately 45 percent of the households indicated the presence of irrigated fields in the community and about 63 percent have access to fishing waters. In addition, about 25 percent of the households engage in irrigated agriculture while 16 percent of the households undertake fishing.

Agricultural modernization through intensification of use of resources, improved technologies and agronomic practices, irrigated agriculture and mechanization has been the long term goal/strategy of almost all the agricultural policies of Ghana including Food and Agriculture Sector Development Policy (FASDEP I and II) and Medium Term Agriculture Sector Investment Plan (METASIP).

Several types of irrigation systems exist in Ghana including informal, formal and commercial irrigation. Irrigation schemes in Ghana also can be classified based on ownership or management and these are private versus public irrigation schemes (refer to Namara *et al*., (2010) for more discussions on types of irrigation systems in Ghana). The public irrigation schemes are managed by the Ghana Irrigation Development Authority (GIDA) under the current policy direction of Ghana Irrigation Development Policy (GIDP). Currently, GIDA has 22 irrigation projects with a total area of about 6,505 hectares (ha). In addition, there are 22 schemes under Small Scale Irrigation Development Project (SSIDP) and 6 schemes under the Small Farms Irrigation Project (SFIP) (MoFA, 2011 and 2015).

Management and utilization of water resources are subjected to several institutions and their legal frameworks. Fisheries are classified under agriculture sector. The legal framework under which fisheries sub-sector operate is the Fisheries Act 625. According to Odame-Ababio (2003), Water Resources Commission (WRC) has the "mandate to regulate and manage Ghana's water resources and coordinate government policies in relation to them." But water resources and its management are under several institutions including ministries of agriculture; water resources, works and housing; etc. Furthermore, WRC (2012) indicated that the National Integrated Water Resources Management (IWRM) Plan present "current baseline situation with respect to the socio-economic context, the biophysical context, the water resources potential, the water demands, the sharing of water with neighboring countries as well as the current management framework as defined by legal instruments in place and roles and functions of institutions." A major observation or conclusion that could be drawn on the legal frameworks and institutions on water resources is that they are still fragmented and mainly sector-specific. The regulations put the mandate of water resource management and utilization into the hands of several agencies and ministries and this requires further streamlining.

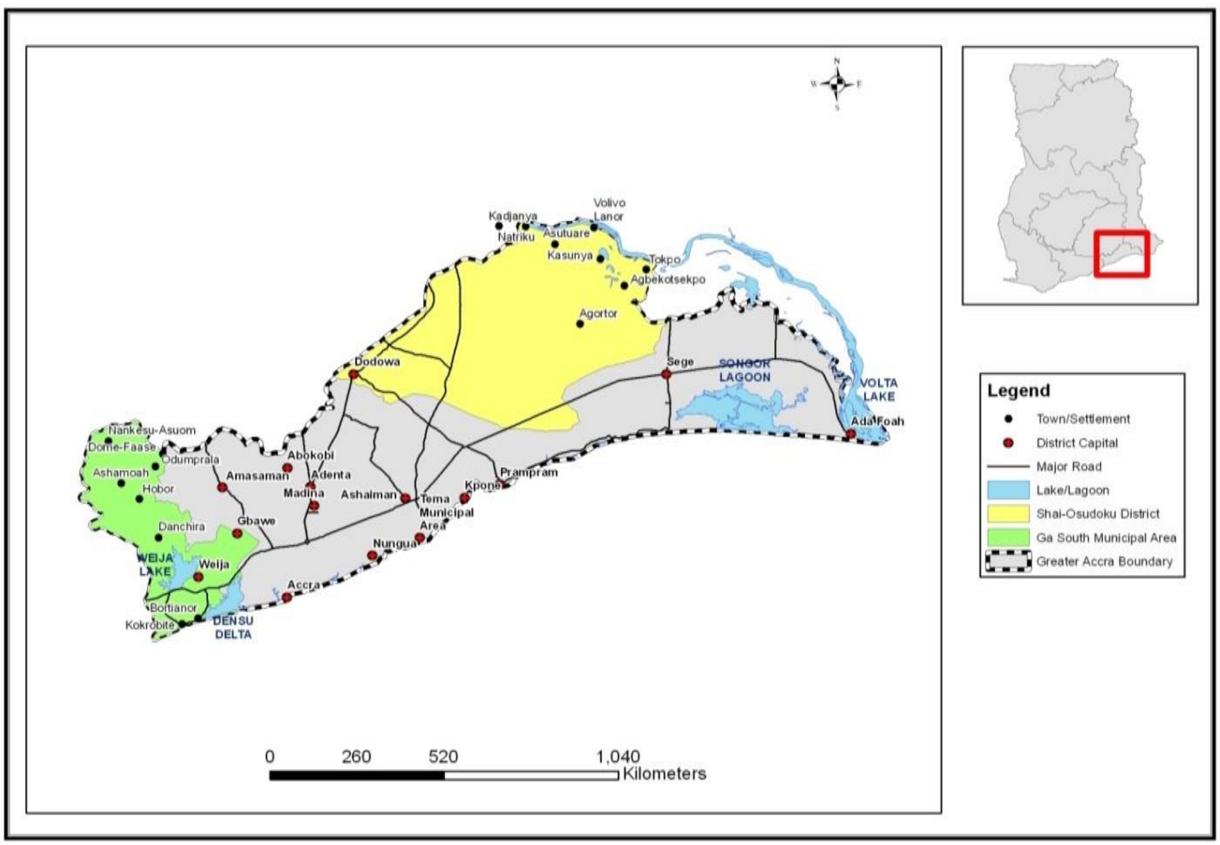
2.3 Methodology and Data Sources

This section first describes the study area. Survey design and data are next presented. The analytical framework including the derivation of the reduced-form equations for the child health and nutrition status based on a model of household decisions on resource allocation are then discussed. The panel data analysis techniques including empirical models and empirical issues (including a selection of variables) are finally addressed.

2.3.1 Study Area

The survey data used for the study was undertaken in 16 communities and their environs in the Shai-Osudoku district and Ga South Municipal in the Greater Accra region of Ghana. The communities were selected due to the presence of multiuse water systems serving both economic and domestic purposes and deficiencies in water supply and sanitation services. In the case of Ga South Municipal, communities along the coast were of interest due to the presence of the sea (Gulf of Guinea) being used for fishing. Furthermore, communities along the Densu catchment area were also of interest. For Shai-Osudoku district, communities along the Volta river and its catchment area were selected. The Volta river is used for irrigated agriculture through the Kpong Irrigation Scheme (KIS) and for fishing. Greater Accra region based on 2010 population and housing census (PHC) is the second most populous region in Ghana, after the Ashanti region. Its location along the coast and also the presence of major water bodies including the Volta and Densu rivers makes it ideal for the main purpose of the study such as understanding the linkages between agriculture, and water, sanitation and hygiene and health outcomes. Figure 2.1 presents the map of the study sites.

Figure 2.1: Map of Study Sites indicating Districts and Communities



Source: Author's own presentation

2.3.2 Survey Design and Data

The study uses multipurpose household-level data collected for the AG-WATSAN Nexus Project (a household water quality testing and information experiment) undertaken from April-May 2014 to May-June 2015 by the Center for Development Research (ZEF) of the University of Bonn, Germany in collaboration with the Institute of Statistical, Social and Economic Research (ISSER) of the University of Ghana, Legon.

The data set used for this study was collected with the idea of studying into details the linkages between WASH and agriculture and health outcomes, and thus involves several household and individual variables on health, agriculture, and WASH. The household surveys solicited for detailed information concerning household demographics, household assets and expenditures, irrigated agriculture and fishing, interviewers' observations, household health, water, sanitation and hygiene, and anthropometric measurements of children (0-8 years of age). The anthropometric measurements for children included height (in centimeters) and weight (in kilograms).

The AG-WATSAN Nexus Project had ethical clearance from ZEF and Noguchi Memorial Institute for Medical Research (NMIMR) of University of Ghana, Legon. The study sampled 16 public basic schools with the random drawing of 32 samples (students from grade five to eight) from each public basic school. In each community, one public basic school (comprising of both junior high school (JHS) and primary) was selected. Students, therefore, represented the households as the sampling unit. Selected siblings were replaced with students of similar gender and grade from the same basic school in order to obtain unique households. The respondents for the surveys were household heads or members who are the most knowledgeable persons on the module or section of the questionnaires.

The study targeted a total sample of 512 households but at the end of the baseline data collection (wave one), 505 households were successfully enumerated indicating a success rate of 98.6 percent. There were 404 children under-eight years of age in these households. Six months (November-December 2014) after the baseline data collection, a first follow-up survey (wave two) was undertaken using an abridged version of the baseline survey instruments. The first follow-up survey yielded interviews with 486 households, which is a success rate of 96.24 percent. The number of children in wave two was 461. The increase in the number of children in wave two compared to wave one was largely as a result of new births and inclusion of children missed during wave one data collection due to age discrepancies. In January-February 2015, we conducted a second follow-up survey (wave three) using the same survey instruments as the first follow-up survey. During the second follow-up survey, we successfully enumerated 478 households, representing an attrition rate of 5.35 percent. There were 456 children in the households for the wave three data. The endline survey (wave four) was conducted in May-June

2015 using an abridged version of the baseline survey instruments. 390 children in 437 households were enumerated. In total, there were 1711 children under-eight years of age in the four waves of data collection. About 61.13 percent of the children were enumerated in all the four survey waves, 25.25 percent in three, 7.42 percent in two and finally, 6.20 percent in only one.

We use the complete set of 1711 of children for the analysis on diarrhea incidence. In the final analysis on the anthropometric outcomes, we rely on information on 1270 children. The samples on anthropometrics reduced since not all children were measured during the data collection due to school and other household activities. Also, data cleaning using the STATA command *bacon* (Weber, 2010) to correct for outliers in the anthropometric outcomes further reduced the sample. All the data were entered with CSPro version 5.0 (U.S. Census Bureau, 2013) while the analysis is performed using STATA version 14.0 (StataCorp, 2015).

2.3.3 The Model

We model the determinants of child health and nutrition status, especially the synergetic or combined effects or tradeoffs of multipurpose water systems, and water, sanitation and hygiene and other household characteristics. In the anthropometry literature, child health and nutrition status are modeled based on the concepts of reduced form and production function (Strauss, 1990). Strauss (1990) argued that some of the previous studies confused the two concepts, therefore estimating results comprising of both approaches using ordinary least squares (OLS). This is problematic in the sense that issues related to endogeneity, simultaneity and reverse causality were ignored, generating biased estimates, especially in studies not applying simultaneous equations estimation.

In this study like previous ones (Strauss, 1990; Pal, 1999; Thomas *et al*., 1990), we estimate reduced form equations on child health and nutrition outcomes in Ghana using individual and household characteristics. The reduced form equations for child health (diarrhea incidence) and nutritional status (anthropometric measures) are derived from a model of multimember household behavior in which households make consumption and production decisions for each individual. Here, we assume that households maximize the long run utility function of each individual as a function of health/morbidity and nutritional outcomes (including diarrhea incidence, height, weight, weight-for-height and body mass index), leisure, and consumption of food and non-food items. Households also face several constraints including time, budget, and health production functions. Then the reduced form equations for child health and nutrition status could be derived as:

(1) $Y_c = Z(X_i, X_h, \varepsilon_c)$

where Y_c represent the child health and nutrition indicators. X_i and X_h are vectors of individual and household characteristics and ε_c is the stochastic/disturbance/error term. For brevity and notational convenience, we ignore the notation it which indicates the cross-sectional and time dimension of the data we rely upon for the analysis of the reduced form equations. We include two broad categories of exogenous variables: individual and household characteristics. The household characteristics are categorized as: (i) ecological/environmental factors (ii) socio-economic characteristics and (iii) parental characteristics. We further categorized the ecological/environmental factors into two broad groups: (i) multipurpose water systems, and (ii) water, sanitation and hygiene practices. Socio-economic characteristics include income, and other dwelling characteristics. The individual characteristics include age, gender, etc. of children in the households. Additional variable such as whether child is the biological son or daughter of the household head are included to indicate intra-household distribution of resources.

By pursuing only random effects estimates in a panel data analysis, we are able to include time invariant variables such as gender, education, and ethnicity of the household head. The random effects model is more applicable to our data due to the short duration of the data collection and study. A potential problem that arises is treating all the variables as exogenous whereas in reality variables are correlated with each other. Relying on a panel data having limited time frame between the survey rounds, means we are not able to include community characteristics such as quality of health and education infrastructures, roads and prices which have been found to be important determinants of child health and nutritional status. Additionally, we do not have data on anthropometric measures of parents and therefore our estimates ignore the importance of such measures on child health and nutrition. Since we are dealing with all children between zero and eight years of age, we ignore also the importance of breastfeeding on child health and nutrition outcomes, instead of the parsimonious approach employed by Strauss (1990) that restricted their sample and analysis to only preschool children (i.e. between 2 to 8 years). We also undertake sub-group analysis by restricting the sample for children under five years of age.

2.3.4 Variables and Descriptive Statistics

This sub-section presents the variables used in the estimation of the determinants of child health and nutrition outcomes.

2.3.4.1 Dependent Variables

The dependent variables used in the study are child diarrhea incidence reported by the respondent and z-score for anthropometrics such as height for age, weight for age, weight for height and body mass index for age. Diarrhea incidence is a self-reported measure of a child having “three or more loose stools in the past 24-hour period”-the standard World Health Organization definition. Information on diarrhea incidence was collected by using a recall period of the last/past 4 weeks, with respondents being household head or spouse.

Anthropometric outcomes such as height, weight, weight for height and body mass index are used as the nutritional indicators. The *z*-score or standard deviation is used as it is the WHO recommended measure for anthropometrics. We rely on zanthro Stata command to calculate the z-scores (Vidmar *et al*., 2013) since we use data for children under eight years of age. The *zanthro* using the WHO version of the growth chart estimates z-scores for children between zero and ten years for some of the indicators (i.e. weight for age) and 0 to 19 years for height-for-age and BMI-for-age. We also rely on WHO cut-off points on anthropometrics to correct for outliers or "biologically implausible values (BIVs)" in the z-scores or standard deviations of the height-for-age, weight-for-age, weight-for-height, and body-mass-index-for-age. Age in months is used in generating z-scores in the Stata command. Furthermore, z-scores are estimated for only children with the date of birth. The Stata command requires the inputs of child's age, sex, height and weight in estimating the z-scores.

According to Strauss (1990), anthropometric *z*-scores of "less than -3 indicates "severe" malnutrition, between -3 to -2.01 indicates "moderate" malnutrition, -2 to -1.01 indicates "mild" malnutrition, and -1 and above is considered to be normal" (see also Horton, 1986). This is also explored within the context of children being in the normal, overweight, stunting, underweight or wasting category in terms of malnutrition classification. The summary statistics of the child health and nutrition indicators are presented in Tables 2.1 and 2.2. In all the four survey waves, about 21 percent of the children under eight years of age are chronically malnourished (stunted) with height-for-age z-score being less than -2. However, obesity is relatively low with about two percent of the children in all the four survey waves suffering from this condition. The level of malnutrition is relatively similar in all the four survey waves and comparable to the national average of Ghana. Using the long run measures of malnutrition (i.e. height-for-age z-score and weight-for-age z-score) indicate relatively high incidence compared to the short run measure (i.e. weight-for-height z-score)**.** Finally, the z-scores are not uniform across survey waves due to missing anthropometric data emanating from the unavailability of all children being measured during data collection.

Table 2.1: Summary Statistics of Child Health and Nutrition Indicators

Variable	Description	Wave I Mean (S.D.)	Wave II Mean (S.D.)	Wave III Mean (S.D.)	Wave IV Mean (S.D.)	All Mean (S.D.)
CHILD_DIARR1MNTH	Child had diarrhea in the past 4 weeks	0.06(0.24)	0.07(0.25)	0.07(0.26)	0.03(0.17)	0.06(0.24)
CHILD_HEIGHT	Child's height in centimeters (cm)	97.26(15.83)	101.31(15.16)	101.73(16.40)	103.80(16.05)	100.98(16.03)
CHILD_WEIGHT	Child's weight in kilograms (kg)	14.71(4.31)	15.52(4.17)	15.78(4.43)	16.60(4.31)	15.63(4.35)
CHILD_BMI	Child's body mass index (BMI) measured as kg/m2	15.38(1.94)	15.02(2.13)	15.17(2.11)	15.38(2.13)	15.23(2.08)
CHILD_HAZ	Height-for-age z-score	-1.19 (1.40)	-0.96 (1.25)	-0.88 (1.219)	-1.08(1.31)	-1.02 (1.30)
CHILD_WAZ	Weight-for-age z-score	-0.85 (1.13)	-0.84 (1.15)	-0.78 (1.15)	-0.79 (1.046)	-0.81 (1.12)
CHILD_WHZ	Weight-for-height z-score	-0.35 (1.25)	-0.42(1.34)	-0.48(1.21)	-0.24(1.33)	-0.38 (1.28)
CHILD_BMIZ	Body-mass-index-for-age z-score	-0.17 (1.34)	-0.32 (1.34)	-0.37 (1.30)	-0.18 (1.34)	-0.27(1.33)
MALNUTRITION	% in malnutrition (CHILD_HAZ < -2)	0.27 (0.44)	0.20 (0.40)	0.17 (0.38)	0.20(0.40)	0.21 (0.41)
OBESE	% being obese (CHILD_HAZ > +2)	0.03 (0.17)	0.01(0.11)	0.03(0.16)	0.01(0.11)	0.02(0.14)

Table 2.2: Z-Score Classification of Nutritional Status

Z-Score Categories	Degree of Malnutrition	Wave I Percentage	Wave II Percentage	Wave III Percentage	Wave IV Percentage	All Percentage
Height-for-age z-score						
Less than -3.00	Severe	8.67	7.32	4.23	7.87	6.83
-3 to -2.01	Moderate	17.67	12.42	12.70	11.99	13.66
-2 to -1.01	Mild	26.67	25.80	28.04	32.21	28.04
-1.00 and above	Normal	47.00	54.46	55.03	47.94	51.47
Weight-for-age z-score						
Less than -3.00	Severe	2.96	3.19	1.57	1.16	2.22
-3 to -2.01	Moderate	10.86	11.18	10.70	10.81	10.88
-2 to -1.01	Mild	30.26	30.03	30.03	29.34	29.94
-1.00 and above	Normal	55.92	55.59	57.70	58.69	56.95
Weight-for-height z-score						
Less than -3.00	Severe	1.67	2.87	1.59	1.87	1.99
-3 to -2.01	Moderate	2.67	3.82	3.70	4.12	3.57
-2 to -1.01	Mild	19.00	20.06	23.28	14.98	19.70
-1.00 and above	Normal	76.67	73.25	71.43	79.03	74.74
Body-mass-index-for-age z-score						
Less than -3.00	Severe	2.00	3.57	2.12	1.95	2.41
-3 to -2.01	Moderate	1.33	3.25	4.50	5.06	3.54
-2 to -1.01	Mild	19.67	22.40	24.34	17.90	21.40
-1.00 and above	Normal	77.00	70.78	69.05	75.10	72.65

Previous studies suggest a wide range of individual, household and community characteristics as the determinants of child health and nutrition outcomes. Several of these variables are included in the empirical model as the important factors affecting child health and nutrition outcomes. Table 2.3 presents the descriptive statistics of the variables used in the empirical models. The *apriori* expectations of the independent variables in relation to the dependent variables are also discussed.

2.3.4.2 Individual or Child Characteristics

MALE_CHILD indicates the gender of the child (0=female, 1=male). In sub-Saharan Africa where cultural and societal differences exist in terms of preferences for the gender of children, male children are usually given much value and attention leading to good health than their female counterparts. Other studies (Morduch and Stern (1997)) find evidence of a negative correlation between female children and nutrition. We expect MALE_CHILD to be negatively related to diarrhea incidence and positively related to anthropometric outcomes.

AGE_YEARS indicates the age of the child in years and AGE_MONTHS is the age of the child in months. The health of children is largely influenced by their age, with the first years having a higher probability of sickness or infections. It is most probable that older children will have less diarrhea incidence. According to Mihrete *et al*., (2014), the age of the child is significantly related to diarrhea morbidity. The diarrhea morbidity decreases from the age of 24 months and higher. In other words, the risk of diarrhea morbidity is high for children under 24 months of age (Ssenyonga *et al*., 2009). We expect AGE_YEARS and AGE_MONTHS to be negatively related to diarrhea. The quadratic forms of the AGE_YEARS and AGE_MONTHS are included to cater for nonlinearity in the relationship between age and diarrhea incidence. Several factors affect the nutrition of children in terms of food intake. Some empirical evidence suggests of malnutrition increasing with the age of children due to inadequate food calorie intake and feeding practices. Breastfeeding among children under two years of age potentially offsets poor nutrition from inadequate feeding practices and food calorie intake. We expect AGE_YEARS and AGE_MONTHS to have an ambiguous relationship with nutritional status of children.

CHILD_NHIS is a dummy variable that is equal to one if the child holds valid national health insurance scheme (NHIS) card, and to zero otherwise. This indicator to certain extent reveals household health investment in children. Holding valid NHIS card can increase risk-loving behavior among individuals making them more vulnerable to diarrhea cases and malnutrition. Alternatively, usage of NHIS (indicating access to health care) could boost the resistance capacity of children to diarrhea diseases, leading to improved nutrition. It is expected that holding a valid NHIS card will have an ambiguous role with diarrhea incidence and nutrition status.

BIO_CHILD is an indicator variable, which is one if the child is the son or daughter of the household head and zero otherwise. This variable addresses intra-household distribution of resources. Biological children are usually given preferential treatment in many African households. The extra attention given to biological children in many African households is expected to have negative relationships with diarrhea incidence and positively associated with anthropometrics.

2.3.4.3 Socio-economic Characteristics

Household socio-economic characteristics are important determinants of child health and nutrition outcomes. In this study, we include several household socio-economic indicators such as income, household size, and access to electricity in modeling the determinants of child health and nutrition. HHINCOME is a categorical variable for the average monthly household income. Income of the household indicates their spending power and ability to afford health and nutrition related expenditures, which are important inputs in the child's health production, function (Thomas *et al*., 1990; Pal, 1999). With this, we expect a negative association with diarrhea incidence and positive relationship with nutritional status. In addition, we include household access or use of the internet (INTERNET_HH) as an additional variable to study the role of technology and information on child health and nutrition. DWELLING_TYP is a dummy variable on the type of housing used by the household. It is an additional measure of income effects on child health and nutrition status.

HHSIZE is the number of household members in the dwelling. The square of household size (HHSIZE_SQ) is included to take care of the nonlinearity of the relationship with child health and nutrition outcomes. Family or household size indicates the number of units in which households have to allocate resources in terms of consumption and production decisions. In the case of consumption, it is a liability in the sense that household resources have to be shared among a large number of people, which is further exacerbated by having little or limited resources. For instance, large household or family size means more people to feed. In terms of production, it is an asset since more people in the household could translate to more labor for agriculture and other household activities. FEMALE_U15 is the number of female children under 15 years of age present in the household and FEMALE_ABOV15 is the number of female household members who are 15 years of age or above and they represent the gender dynamics of household structure that plays vital roles in terms of division of labor for household chores or activities. We, therefore, expect an ambiguous relationship between health and nutritional status of children and family size, and a number of adults and young females (see Pal, 1999).

ELECTRIC_HH represent whether the household is connected to the national grid. The variable takes the value of 1 if the household has electricity and 0 otherwise. Some empirical evidence (Thomas and Strauss, 1992) shows that availability of electricity is positively associated with nutritional status of children. We expect the electricity indicator to have a similar link as household income.

URBAN_HH is the variable to index the locality of the household. The variable is coded as 1 if the household is located in an urban district (Ga South) and 0 otherwise (Shai-Osudoku district). In many developing countries including Ghana, electricity and other social and economic infrastructures are of better quality in urban areas than in rural areas. The level of urbanization may also be a measure of the relative prices of goods and services in a given locality. We expect URBAN_HH to be negatively associated with diarrhea incidence and positively associated with nutritional status. This is also in the direction of Pongou *et al.*, (2006) finding that nutritional status of children in urban cities was better off than their counterparts in rural cities in Cameroon.

EVERTREAT is a dummy variable for households being allocated into either treatment or control group. The variable is coded as 1 if the household was assigned to the treatment group and 0 control group. This variable is introduced to take into account the research design and survey implementation. Due to a limited period of the study, we expect the treatment allocation variable to have ambiguous effects on child health and nutrition status.

2.3.4.4 Parental/Household Head Characteristics

Several studies have shown that household head or parental characteristics have effects on child health and nutrition. We include the education of household head, age and other demographic indicators in our models. AGE_HEAD measures the age of the household head in years. The square of the age of the household head (AGE_HEAD_SQ) is included in the analysis to capture nonlinear relationship. Age variables measures experience in most of the household production functions and we expect them to perform the same role in this study. We expect the age of household head to be negatively related to diarrhea incidence and positively associated with nutritional status. MALE_HEAD is the variable indicating the gender of the household head (1=male, 0=female). The gender of the household head may play a crucial role in household resource acquisition and allocation. Female headed households tend to be widowed or divorced, placing an additional burden on them in addressing household needs. Gender of the household head being male is expected to be positively related to diarrhea and nutritional outcomes. MAR_HEAD is discrete variable for the marital status of the household (1=married, 0=otherwise). Married household head is expected to have an ambiguous relationship with child health and nutrition.

RELG_HEAD is the dummy variable to capture the religion of the household head. The variable is coded as one if the household is a Christian and zero otherwise. Not many studies have been carried out on the role of religion on child health and nutrition. Therefore we expect the religion indicator to have an ambiguous relationship with child health and nutrition outcomes.

ETHNIC_HEAD is a dummy variable indexing the ethnicity of the household head (1=Ga/Adangbe, 0=otherwise). Ethnicity is expected to capture other genetic traits and social dimensions, which are linked to social groups that could not be measured during data collection. Ga/Adangbe is the native ethnic group in the study sites (Greater Accra region). Natives have additional social status and power in terms of land ownerships, etc. In our study sites, there is a strong presence of Ewe ethnic group that is almost at par (in terms of proportions) with the Ga/Adangbe ethnic group. Therefore, we expect ethnicity variable to have an ambiguous relationship with diarrhea and nutritional status.

LIT_HEAD is a dummy variable to capture the literacy status of the household head (1= can read and write, 0=otherwise). Additionally, we include the education level of the household head as a categorical variable (EDUC_HH).

2.3.4.5 Multipurpose Water Systems Indicators

IRRIG_AGRIC is an indicator variable, which indexes whether household participates in irrigated agriculture. IRRIG_AGRIC is coded as one for households engaging in irrigated agriculture and zero otherwise. According to WHO (2013), food contamination through water from irrigation facilities is among the causes of diarrhea. Irrigation fields and water bodies serve as breeding grounds for mosquitoes that lead to high incidence of malaria in those areas (Fobil *et al*., 2012). Aside the negative externalities are also the positive aspects of irrigated agriculture. Involvement in irrigation activities could enhance household income and availability of food all year round. This has the potential of counterbalancing the negative health benefits from irrigation water sources and irrigated agriculture.

FISHING_HH is a dummy variable that is one, if the household engages in fishing, zero otherwise. Based on WHO (2013) diarrhea morbidity could be caused by eating seafood and fish from contaminated water sources. Furthermore, the spatial dimension in terms of surface water bodies (including fishing waters and irrigation water sources) could explain the mortality from infectious diseases in urban areas (Fobil *et al*., 2012). Open defecation around water bodies is among the causes of diarrhea and malaria in many developing countries. However, household engagement in fishing and location in communities with fishing waters could have positive benefits in terms of availability of nutritious food through consumption of fish and other seafood that could offset the negative health risks in residing in fishing localities and actual participation in fishing.

2.3.4.6 Water, Sanitation and Hygiene Indicators

Thomas and Strauss (1992), Jalan and Ravillion (2003), Checkley *et al*., (2004), Pal (1999), and Pongou *et al*., (2006) have all demonstrated the importance of behavioral, environmental and ecological factors on child health and nutrition outcomes. Among other things, we include household access to improved water, sanitation and hygiene practices. These public health facilities are expected to have both direct and indirect effects on child health and nutrition status. We also rely on the standard WHO classifications of improved water and sanitation. Here, we also make use of the drinking water ladder and sanitation ladder classifications and not only the binomial classification of either improved or unimproved. We also explore the quality of the surroundings of the dwelling. The indicators used and their definitions are as follows: IMPROV_DRINK is dummy variable indicating whether households use improved main drinking water sources based on JMP classification (1=yes; 0=no). IMPROV_GP is a dummy variable indexing whether households rely on improved water sources for general purpose based on WHO's JMP classification (1=yes; 0=no). MULTI_DRINK is an indicator variable indicating whether the households rely on more than one drinking water source (i.e. household have both primary and secondary drinking water sources) (1=yes, 0=no). MULTI_GP is a dummy variable for households using both primary and secondary general purpose water sources (1=yes, 0=no). TREAT_WAT is a discrete variable, which is one if household treats water to make it safer to drink, zero otherwise.

HSE_CLEAN is an indicator variable, which is coded as one if the household was clean through interviewer observation, zero otherwise. DRINK_POT is an indicator variable for the type of storage container households use in storing drinking water (1=pot; 0=otherwise). HWASH_SOAPDE is a dummy variable, which is one if the respondents reported of using soap or detergent in washing the hands and zero otherwise. OVERALL_CONTASIZE is a categorical variable indicating whether the household has low, small, medium or large water storage containers for storing drinking and general purpose water. We include this measure to study the effects of household storage container size on child health and nutrition status. IMPROV_SAN is an indicator variable which indicates whether the households rely on improved sanitation based on JMP classification (1=yes; 0=no). DRINK_TIME is a number of minutes it takes for a household to go for drinking water and return to the dwelling. LATRINE indicates the presence of latrine in the household.

Table 2.3: Description and Summary Statistics of Variables used in the Empirical Models

Variable	Description	Wave I Mean (S.D.)	Wave II Mean (S.D.)	Wave III Mean (S.D.)	Wave IV Mean (S.D.)	All Mean (S.D.)
A: Individual or child characteristics						
MALE_CHILD	Gender of the child. 0=female; 1=male	0.52(0.50)	0.52(0.50)	0.53(0.50)	0.51(0.50)	0.52(0.50)
AGE_YEARS	Age of the child in years	3.61(2.00)	4.04(2.12)	4.00(2.14)	4.38(2.24)	4.00(2.14)
AGE_MONTHS	Age of the child in months	48.18(23.51)	53.44(25.55)	53.67(25.66)	57.11(26.12)	53.13 (25.42)
AGE_MONTHS_SQ	Squared of the age of the child in months	2872.43(2279.59)	3507.59(2667.82)	3537.13 (2709.37)	3942.52(2899.65)	3468.11(2674.19)
CHILD_NHIS	Child holds valid NHIS card. 0=No; 1=Yes	0.32(0.47)	0.23(0.42)	0.19(0.39)	0.29(0.46)	0.25(0.43)
BIO_CHILD	Dummy for son/daughter of the household head. 0=No; 1=Yes	0.77(0.42)	0.75(0.43)	0.72(0.45)	0.71(0.45)	0.74(0.44)
B: Parental/household head characteristics						
AGE_HEAD	Head's age (years)	45.96 (10.47)	46.49 (10.83)	47.25(11.65)	47.14(11.05)	46.72(11.02)
AGE_HEAD_SQ	Squared of the age of household head	2221.86 (1057.46)	2278.53 (1118.76)	2368.34 (1240.28)	2344.28 (1147.10)	2304.07 (1145.48)
RELG_HEAD	Head's Christian	0.80 (0.40)	0.78 (0.41)	0.76(0.42)	0.77(0.42)	0.78(0.42)
ETHNIC_HEAD	Head is Ga/Adangbe	0.41(0.49)	0.44(0.50)	0.43(0.50)	0.46(0.50)	0.43(0.50)
LIT_HEAD	Household head can read and write in English (self-reported)	0.42(0.49)	0.42(0.49)	0.42(0.49)	0.41(0.49)	0.42(0.49)
MAR_HEAD	Head is married	0.76(0.43)	0.73(0.44)	0.76(0.43)	0.75(0.43)	0.75(0.43)
MALE_HEAD	Head is male	0.81(0.39)	0.79(0.40)	0.80(0.40)	0.79(0.40)	0.80(0.40)
EDUC_HH	Highest educational qualification of household head. 1=None; MLSC/BECE=2; 3= SSCE and above	1.45(0.67)	1.46(0.67)	1.47(0.67)	1.45(0.69)	1.46(0.67)
C: Water, sanitation and hygiene indicators						
IMPROV_DRINK	Household uses improved drinking water source	0.66(0.47)	0.67(0.47)	0.65(0.48)	0.73(0.44)	0.68(0.47)
IMPROV_GP	Household uses improved general purpose water source	0.51(0.50)	0.49(0.50)	0.39(0.49)	0.62(0.49)	0.50(0.50)
MULTI_DRINK	Household has multiple drinking water sources	0.40(0.49)	0.86(0.35)	0.53(0.50)	0.62(0.49)	0.61(0.49)
MULTI_GP	Household has multiple general purpose water sources	0.40(0.49)	0.66(0.48)	0.40(0.49)	0.54(0.50)	0.50(0.50)
HSE_CLEAN	Dwelling is clean or average	0.82(0.38)	0.77(0.42)	0.72(0.45)	0.78(0.42)	0.77(0.42)

Table 2.3 continued

Variable	Description	Wave I Mean (S.D.)	Wave II Mean (S.D.)	Wave III Mean (S.D.)	Wave IV Mean (S.D.)	All Mean (S.D.)
IMPROV_SAN	Household uses improved sanitation	0.46(0.50)	0.44(0.50)	0.44(0.50)	0.42(0.49)	0.44(0.50)
LATRINE	Presence of latrine in the dwelling	0.37(0.48)	0.27(0.44)	0.23(0.42)	0.34(0.48)	0.30(0.46)
DRINK_TIME	Time taken to and from main drinking water source	13.32(12.13)	10.15(12.57)	12.33 (12.04)	12.28(13.98)	11.94(12.73)
OVERALL_CONTASIZE	Category of water storage container. 1=Low; 2=Small; 3=Medium; 4=Large	1.99(1.09)	2.77(1.07)	2.57(1.13)	2.52(1.05)	2.48(1.12)
DRINK_LADDER	Classification of drinking water sources based on JMP drinking water ladder. 1= Piped water on premises; 2= Other improved; 3= Unimproved sources; 4= Surface water	2.50(0.90)	2.50(0.81)	2.52(0.85)	2.42(0.78)	2.49(0.84)
SAN_LADDER	Classification of sanitation based on JMP sanitation ladder. 1= Improved sanitation facilities; 2= Shared sanitation facilities; 3= Unimproved facilities; 4= Open defecation	2.69(1.14)	2.78(1.10)	2.77(1.13)	2.79(1.13)	2.76(1.12)
LQUDWASTE	Disposal of liquid waste. 1=Thrown onto compound; 0=otherwise	0.58(0.49)	0.78(0.42)	0.71(0.46)	0.47(0.50)	0.64(0.48)
SOLIDWASTE	Disposal of solid waste. 1=Improved waste disposal (i.e. use of public dump/garbage center or collection by local authority or collection by private firm); 0=otherwise	0.15(0.36)	0.19(0.39)	0.15(0.36)	0.22(0.42)	0.18(0.38)
D: Multipurpose water systems indicators						
AGRIC_HH	Dummy for whether household engages in agriculture and/or allied activities; 1=Yes; 0=No	0.80(0.40)	0.87(0.34)	0.86(0.35)	0.88(0.33)	0.85(0.36)
IRRIG_AGRIC	Dummy for whether household participates in irrigated agriculture, 1=Yes; 0=No	0.29(0.45)	0.25(0.43)	0.18(0.39)	0.20(0.40)	0.23(0.42)
FISHING_HH	Dummy for whether household engage in fishing, 1=Yes; 0=No	0.20(0.40)	0.38(0.49)	0.26(0.44)	0.19(0.39)	0.26(0.44)

Table 2.3 continued

Variable	Description	Wave I Mean (S.D.)	Wave II Mean (S.D.)	Wave III Mean (S.D.)	Wave IV Mean (S.D.)	All Mean (S.D.)
E: Socio-economic Characteristics						
DWELLING_TYP	Type of dwelling. 1=Household resides in separate house or bungalow or semi-detached house or flat or apartment; 0=otherwise	0.26(0.44)	0.18(0.39)	0.21(0.41)	0.45(0.50)	0.27(0.44)
EVERTREAT	Dummy for whether household was assigned to treatment for the water quality testing and information experiment, 1=Yes; 0=Control	0.50(0.50)	0.51(0.50)	0.51(0.50)	0.53(0.50)	0.51(0.50)
HHSIZE	Household size	7.59(2.80)	8.16(3.04)	8.08(3.01)	7.98(2.58)	7.96(2.88)
HHSIZE_SQ	Square of the number of household members	65.41(59.27)	75.82(65.40)	74.31(64.82)	70.41(51.38)	71.72(60.93)
ELECTRIC_HH	Household has electricity	0.77(0.42)	0.78(0.42)	0.77(0.42)	0.80(0.40)	0.78(0.41)
URBAN_HH	Household resides in urban district (1= Ga South Municipal, 0=Shai-Osudoku)	0.54(0.50)	0.49(0.50)	0.47(0.50)	0.47(0.50)	0.49(0.50)
HHINCOME	Per monthly income category of household (GHS). 1=≤200; 2=200.1-400; 3=400.1-600; 4=600.1-800; 5= 800.1-1000; 6=>1000; 7= Don't know/missing	2.84(1.55)	2.94(1.83)	2.62(1.70)	3.14(1.63)	2.88(1.70)
INTERNET_HH	Household member(s) use internet facility (at home, internet café, on phone, other mobile device)	0.10(0.30)	0.11(0.31)	0.16(0.37)	0.12(0.33)	0.12(0.33)
FEMALE_U15	Number of female household members below 15 years	1.86(1.10)	1.96(1.22)	1.92(1.22)	1.91(1.23)	1.92(1.20)
FEMALE_ABOV15	Number of female household members 15 years or above	1.91(1.10)	2.03(1.12)	2.13(1.15)	2.21(1.13)	2.07(1.13)
No. of observations	-	404	461	456	390	1,711

Notes: S.D. is the standard deviation. Each row will differ from the number of observations for each wave based on missing values or observation.

2.4 Results and Discussion

Following previous studies (Linnemayr *et al*., 2008; Ayllon and Ferreira-Batista, 2015; Horton, 1986; Senauer and Garcia, 1991), height-for-age z-score, weight-for-age z-score, weight-for-height z-score and body-mass-index-for-age z-score are regressed on a set of individual and household characteristics for all children from zero to eight years of age. In anthropometry literature, these measures represent both the short run and long run nutritional status of children. Longitudinal logit fitted in a random effects model is used to estimate the determinants of diarrhea incidence in the past one month among children under eight years of age.

The results of the effects of multipurpose water systems, and water, sanitation and hygiene and other household characteristics are presented in Table 2.4. In addition to multipurpose water systems indicators such as participation in irrigated agriculture and fishing, water, sanitation and hygiene practices, child characteristics and other household characteristics are included in each regression. For each dependent variable (child health and nutrition outcome), we estimate one reduced form regression. As robustness checks for using dummies of years of a child with the reference group being a child of zero years of age, we run separate regressions using continuous child age variable in months and it's squared value (results available upon request) and the results are similar to those reported in Table 2.4. All the models pass the test of goodness fit with the *P*-value of the Wald test of joint significance (Prob. > chi^2) being less than 5 percent. This implies that in the five regression specifications, the explanatory variables jointly and statistically significantly explain the variation in the dependent variables (i.e. child health and nutrition outcomes). We report robust standard errors for the regressions on anthropometric outcomes.

2.4.1 Effects of Multipurpose Water Systems on Child Health and Nutrition Outcomes

On the variables for multipurpose water systems, we find that household's participation in irrigated agriculture is associated with higher weight-for-age *z*-score, weight-for-height *z-score* and body-mass-index-for-age *z*-score (results in columns (3) to (5)). One possible mechanism through which irrigated agriculture works on child health and nutrition is through high income and food availability for the households. These results indicate that on average, these positive effects of increased income and food availability outweigh the potential negative effects of being in contact with contaminated water sources and other negative externalities. However, household's participation in fishing has no statistically significant effect on child health and nutrition status in the study settings.

2.4.2 Effects of Water, Sanitation and Hygiene on Child Health and Nutrition Outcomes

With regards to the explanatory variables on water, sanitation and hygiene practices, open defecation compared to improved sanitation based on JMP "sanitation ladder" classification is positively and statistically significantly associated with diarrhea incidence. Open defecation compared to improved sanitation is not significantly associated with weight-for-age z-score. However, household use of improved drinking water sources is negatively associated with height-for-age z-score, and not statistically significantly associated with most of the child health and nutrition outcomes. The limited effect of improved drinking water source based on JMP classification on child health and nutrition status may reflect on the inadequacy of such measure in addressing household behaviors on water collection, transport, storage and use. Disposal of liquid waste on the compound of the dwelling and household use of multiple drinking water sources increases the risk of diarrhea incidence. Furthermore, disposal of liquid on the compound is associated with lower weight-for-height *z*-score and body-mass-index-for-age *z*-score and surprisingly positively associated with height-for-age *z*-score. Households' reliance on multiple water sources makes them susceptible to water recontamination, which increases the risk of diarrhea incidence. Likewise, the disposal of liquid waste on the compound of the dwelling affects the cleanliness of the environment, thereby increasing the risk of diarrhea incidence of children. The results indicate that disposal of liquid waste on the compound affects the short run nutritional status compared with the long-run indicators. Simultaneously, the potential problem of water recontamination seems to be an important factor for the diarrhea incidence in the past one month. In our study sample, children seem to respond quickly to current environmental quality in terms of cleanliness of the surroundings as observed in the immediate effects on diarrhea incidence instead of long term measures such as anthropometric outcomes.

Aside from these variables, we do not find statistically significant results for the time taken to obtain drinking water. We also explore the effects of an additional measure of water by using the drinking water "ladder" classification of JMP and the results are not statistically superior to the ones reported here. We also considered other potential WASH variables such as water treatment, presence of latrine in the dwelling, household use of improved general purpose water, self-reported handwashing with soap, household relying on multiple sources of water for general use and observed cleanliness of the dwelling and the results are not statistically superior compared to the ones we reported in Table 2.4.

2.4.3. Effects of Other Household Characteristics on Child Health and Nutrition Outcomes

Taking into consideration the research design for the experiment on water quality testing and information, we include the treatment allocation variable in all regressions to study the effects of the intervention. We do not find any statistically significant effect of the water quality testing and information experiment on child health and nutrition status. The results partly confirm results in Chapter four which found no statistically significant impacts of the water quality testing and information experiment on child health and nutrition status.

Age of child as dummies in year group (compared with the reference group) is significantly and negatively related with height-for-age *z*-score, weight-for-age *z*-score, weight-for-height *z*-score and body-mass-index-for-age *z*-score. The impact of child's age on health is similar when measured as a continuous variable (age in months) (results available upon request). If anything, specifying age the child with dummy variables shows more statistically significant impacts on the health status, and the negative signs are as expected (as the reference group is child of age zero, breastfed and assumed to be more healthy). This finding partly supports other previous studies (see, for example, Linnemayr *et al*., 2008). Also, dummies of age in years are negatively associated with diarrhea incidence, indicating that older children are less likely to experience diarrhea morbidity. Children holding valid NHIS card have a higher likelihood of diarrhea morbidity. This fits into the moral hazard concept in health insurance, where risk aversion behavior is substituted for a more risk loving behavior. The result on the relationship between health insurance and height-for-age *z*-score is similar to Ayllon and Ferreira-Batista (2015) finding no effect of private insurance on height-for-age *z*-score in Brazil.

Children in households whose head completed senior secondary school or above compared with their counterparts whose household heads had no formal qualification have higher weight-for-age z-score, weight-for-height *z*-score and body-mass-index-for-age *z*-score. Similarly, household head's completion of senior secondary school or above compared with their counterparts who had no formal qualification reduces the risk of diarrhea incidence. However, the age of household head is associated with lower body-mass-index-for-age *z*-score. The square of the age of the household head is positively associated with the body-mass-index-for-age *z*-score-indicating non-linear relationship. In our study settings, the ethnicity of the household head had no effect on child health and nutrition status.

Household use of the internet is positively related with weight-for-age *z*-score. This is more than a pure information effect, as the use of internet requires some level of literacy. It may also reflect an additional evidence of income effects through education. The main measure of income effects on child health and nutrition, such as current per monthly income category of the household, is generally mixed. The results on height-for-age z-score meet the *apriori* expectations. Children in households with per monthly income categories of between GHS 200.1 up to GHS 400 and GHS 600.1 up to GHS 800 compared to their counterparts in households with per monthly income less than GHS 200 have higher height-for-age *z*-score. On the contrary, households with per monthly income category of GHS 200.1 up to GHS 400 compared to those with per monthly income category of less than GHS 200 are negatively associated with weight-for-height *z*-score and body-mass-index-for-age *z*-score. Children in households with per monthly income category of GHS 800.1 up to GHS 1000 compared to those with per monthly income category of less than GHS 200 have lower weight-for-height *z*-score and body-mass-index-for-age *z*-score. Also, households with missing income or whose respondents did not know the average per monthly income are positively related with body-mass-index-for-age *z*-score. Missing responses of income could be as result of courtesy bias emanating either from very high or very low income earning households who may feel uncomfortable in reporting their income to "strangers" and in this case data collectors. Households' per monthly income categories have no statistically significant effects on diarrhea incidence and weight-for-age *z*-score.

A household with electricity (i.e. national grid) is associated with higher weight-for-age *z*-score. This result is similar to those found in previous studies. The level of development in terms of social amenities and infrastructure in many developing countries tends to affect child growth. In our study sample, the connection of households to the national grid leads to higher anthropometric outcomes. We included several other explanatory variables on household characteristics and found no statistically significant effects on child health and nutrition status. These variables include dwelling type, household size, and a number of young and adult females and religion of household head. These variables were dropped from the final regression specifications reported in Table 2.4.

Table 2.4: Determinants of Health and Nutrition Status of Children Under Eight Years of Age

VARIABLES	(1) Diarrhea in the past one month	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Weight-for-height z-score	(5) Body-mass-index-for-age z-score
Individual or child characteristics					
Reference: AGE_YEARS_0					
AGE_YEARS_1	-0.241	-0.793*	-0.712***	-0.116	-0.519
	(0.460)	(0.477)	(0.275)	(0.504)	(0.466)
AGE_YEARS_2	-0.325	-0.595	-0.991***	-0.207	-0.764*
	(0.451)	(0.429)	(0.279)	(0.471)	(0.433)
AGE_YEARS_3	-0.872*	-0.558	-0.821***	0.088	-0.507
	(0.468)	(0.423)	(0.278)	(0.461)	(0.422)
AGE_YEARS_4	-1.305***	-0.292	-0.858***	-0.223	-0.872**
	(0.481)	(0.413)	(0.273)	(0.455)	(0.414)
AGE_YEARS_5	-1.524***	0.001	-0.939***	-0.561	-1.291***
	(0.491)	(0.416)	(0.272)	(0.458)	(0.417)
AGE_YEARS_6	-2.405***	0.007	-0.895***	-0.495	-1.198***
	(0.653)	(0.412)	(0.267)	(0.459)	(0.412)
AGE_YEARS_7	-2.198***	-0.011	-0.973***	-0.653	-1.371***
	(0.647)	(0.406)	(0.272)	(0.463)	(0.414)
AGE_YEARS_8	-1.374	0.024	-1.223***	-1.023*	-1.819***
	(1.127)	(0.446)	(0.302)	(0.534)	(0.434)

Table 2.4 continued

VARIABLES	(1) Diarrhea in the past one month	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Weight-for-height z-score	(5) Body-mass-index-for-age z-score
BIO_CHILD	0.050	0.201	0.179	0.062	0.005
	(0.343)	(0.163)	(0.133)	(0.155)	(0.143)
MALE_CHILD	0.091	-0.054	-0.140	-0.008	-0.044
	(0.253)	(0.100)	(0.095)	(0.110)	(0.099)
CHILD_NHIS	0.888***	-0.006	-0.054	0.006	0.076
	(0.279)	(0.072)	(0.069)	(0.091)	(0.088)
Parental/household head characteristics					
MALE_HEAD	-0.496	-0.115	-0.117	-0.103	0.024
	(0.323)	(0.133)	(0.129)	(0.149)	(0.134)
AGE_HEAD	0.025	0.062*	0.022	-0.037	-0.057**
	(0.079)	(0.035)	(0.030)	(0.029)	(0.026)
AGE_HEAD_SQ	-0.001	-0.001	-0.000	0.000	0.001**
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Reference: EDUC_HH_1					
EDUC_HH_2	-0.311	0.064	0.031	0.083	0.051
	(0.321)	(0.125)	(0.111)	(0.141)	(0.124)
EDUC_HH_3	-0.935*	-0.068	0.252*	0.368**	0.315*
	(0.562)	(0.156)	(0.138)	(0.180)	(0.172)
ETHNIC_HEAD	-0.427	-0.148	-0.083	-0.069	0.026
	(0.280)	(0.117)	(0.100)	(0.118)	(0.109)
Socio-economic characteristics					
EVERTREAT	0.384	-0.112	-0.053	0.001	0.024
	(0.263)	(0.098)	(0.088)	(0.100)	(0.099)
INTERNET_HH	-0.568	0.095	0.148*	0.079	0.099
	(0.452)	(0.092)	(0.078)	(0.116)	(0.113)
ELECTRIC_HH	0.024	0.102	0.172*	0.084	0.047
	(0.313)	(0.111)	(0.099)	(0.115)	(0.107)
Reference: HHINCOME__1					
HHINCOME__2	0.159	0.174***	-0.071	-0.187*	-0.224**
	(0.336)	(0.064)	(0.077)	(0.100)	(0.103)
HHINCOME__3	0.318	0.082	-0.044	-0.116	-0.146
	(0.380)	(0.072)	(0.086)	(0.114)	(0.114)
HHINCOME__4	-0.037	0.186*	0.022	-0.111	-0.088
	(0.512)	(0.109)	(0.085)	(0.121)	(0.127)
HHINCOME__5	0.288	0.119	-0.043	-0.358**	-0.371**
	(0.640)	(0.114)	(0.130)	(0.176)	(0.184)
HHINCOME__6	0.411	0.059	0.011	0.057	0.017
	(0.747)	(0.174)	(0.128)	(0.200)	(0.203)
HHINCOME__7	0.389	-0.073	-0.032	0.205	0.264**
	(0.543)	(0.110)	(0.123)	(0.140)	(0.134)
URBAN_HH	0.071	0.075	0.122	0.047	0.084
	(0.299)	(0.119)	(0.104)	(0.117)	(0.108)

Table 2.4 continued

VARIABLES	(1) Diarrhea in the past one month	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Weight-for-height z-score	(5) Body-mass-index-for-age z-score
Water, sanitation and hygiene indicators					
IMPROV_DRINK	-0.174	-0.131*	-0.081	0.026	0.044
	(0.267)	(0.075)	(0.075)	(0.090)	(0.089)
Reference: SAN_LADDER _1					
SAN_LADDER_2	0.156	0.038	-0.018	0.025	0.076
	(0.419)	(0.086)	(0.064)	(0.087)	(0.085)
SAN_LADDER_3	-0.502	-0.127	-0.030	0.095	0.081
	(0.508)	(0.114)	(0.090)	(0.125)	(0.122)
SAN_LADDER_4	0.811**	0.012	0.140*	0.034	0.094
	(0.388)	(0.100)	(0.081)	(0.100)	(0.101)
LQUDWASTE	0.649**	0.145**	-0.017	-0.182**	-0.164**
	(0.290)	(0.061)	(0.055)	(0.074)	(0.074)
MULTI_DRINK	0.675**	-0.039	-0.024	0.110	0.113
	(0.266)	(0.058)	(0.058)	(0.075)	(0.071)
DRINK_TIME	0.008	0.000	-0.002	-0.001	-0.003
	(0.009)	(0.002)	(0.002)	(0.002)	(0.003)
Multipurpose water systems indicators					
FISHING_HH	0.034	0.110	0.092	-0.030	-0.054
	(0.304)	(0.078)	(0.082)	(0.099)	(0.093)
IRRIG_AGRIC	-0.206	0.098	0.196***	0.195**	0.191**
	(0.313)	(0.068)	(0.067)	(0.099)	(0.094)
Constant	-3.154	-2.544***	-0.776	0.728	1.887***
	(1.970)	(0.821)	(0.789)	(0.827)	(0.716)
Observations	1,517	1,128	1,126	992	1,113
Number of children	548	466	473	432	472
Prob> chi^2	0.000890	2.45e-07	0.0130	0.000239	0

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

2.4.4 Results with Interaction Terms

Table 2.5 presents results from regression specifications including the interaction of indicators of multipurpose water systems and WASH variables. In all regression specifications, we interact household's participation in fishing and irrigated agriculture. We also interact either household's participation in irrigated agriculture or fishing and improved drinking water. Lastly, we interact the three indicators; fishing, irrigated agriculture and improved drinking water. The interaction term of fishing and irrigated agriculture (IRRIG_AGRIC*FISHING_HH) is significant and positive for weight-for-age z-score, weight-for-height *z*-score and body-mass-index-for-age *z*-score -indicating that children in households participating in irrigated agriculture and fishing experience higher nutritional status.

For diarrhea incidence, the negative sign of the coefficient on the interaction between household's participation in fishing and household use of improved drinking water sources

(FISHING_HH*IMPROV_DRINK) indicates children relatively benefit more in terms of reduction in diarrhea incidence from both fishing and improved drinking water sources. The interaction between the three indicators, fishing, irrigated agriculture and improved drinking water sources (FISHING_HH*IMPROV_DRINK*IRRIG_AGRIC) is negatively associated with height-for-age z-score and weight-for-age z-score. This result indicates that the combination of the three indicators may not lead to higher nutritional status as evidenced by the negative and statistically significant coefficient estimate of the interaction term.

Table 2.5: Results with Interaction Terms

VARIABLES	(1) Diarrhea in the past one month	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Weight-for-height z-score	(5) Body-mass-index-for-age z-score
Individual or child characteristics					
Reference: AGE_YEARS_0					
AGE_YEARS_1	-0.254	-0.772	-0.683***	-0.095	-0.506
	(0.463)	(0.481)	(0.262)	(0.507)	(0.471)
AGE_YEARS_2	-0.374	-0.590	-0.973***	-0.189	-0.749*
	(0.452)	(0.434)	(0.266)	(0.475)	(0.438)
AGE_YEARS_3	-0.889*	-0.555	-0.823***	0.092	-0.510
	(0.471)	(0.427)	(0.269)	(0.464)	(0.428)
AGE_YEARS_4	-1.349***	-0.298	-0.866***	-0.214	-0.866**
	(0.483)	(0.416)	(0.264)	(0.458)	(0.419)
AGE_YEARS_5	-1.511***	0.001	-0.929***	-0.544	-1.280***
	(0.492)	(0.420)	(0.260)	(0.460)	(0.421)
AGE_YEARS_6	-2.389***	0.014	-0.877***	-0.476	-1.187***
	(0.653)	(0.417)	(0.257)	(0.462)	(0.417)
AGE_YEARS_7	-2.182***	-0.007	-0.968***	-0.644	-1.376***
	(0.649)	(0.412)	(0.262)	(0.467)	(0.418)
AGE_YEARS_8	-1.388	0.035	-1.213***	-0.970*	-1.808***
	(1.132)	(0.447)	(0.289)	(0.532)	(0.438)
BIO_CHILD	0.015	0.212	0.208	0.070	0.018
	(0.342)	(0.163)	(0.131)	(0.156)	(0.144)
MALE_CHILD	0.064	-0.052	-0.137	-0.007	-0.042
	(0.254)	(0.099)	(0.094)	(0.111)	(0.099)
CHILD_NHIS	0.812***	-0.001	-0.044	0.006	0.081
	(0.280)	(0.072)	(0.068)	(0.091)	(0.088)
Parental/household head characteristics					
MALE_HEAD	-0.495	-0.114	-0.114	-0.094	0.028
	(0.325)	(0.133)	(0.130)	(0.150)	(0.136)
AGE_HEAD	0.044	0.062*	0.020	-0.038	-0.060**
	(0.080)	(0.036)	(0.030)	(0.029)	(0.026)
AGE_HEAD_SQ	-0.001	-0.001	-0.000	0.000	0.001**
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Reference: EDUC_HH_1					
EDUC_HH_2	-0.331	0.063	0.015	0.067	0.037
	(0.322)	(0.126)	(0.113)	(0.142)	(0.125)

Table 2.5 continued

VARIABLES	(1) Diarrhea in the past one month	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Weight-for-height z-score	(5) Body-mass-index-for-age z-score
EDUC_HH_3	-0.890	-0.079	0.184	0.328*	0.275
	(0.560)	(0.154)	(0.137)	(0.181)	(0.173)
ETHNIC_HEAD	-0.363	-0.130	-0.064	-0.067	0.024
	(0.282)	(0.117)	(0.101)	(0.120)	(0.111)
Socio-economic characteristics					
EVERTREAT	0.381	-0.121	-0.067	-0.015	0.014
	(0.264)	(0.098)	(0.088)	(0.101)	(0.100)
INTERNET_HH	-0.543	0.082	0.120	0.066	0.088
	(0.454)	(0.082)	(0.079)	(0.119)	(0.116)
ELECTRIC_HH	0.126	0.069	0.116	0.071	0.023
	(0.322)	(0.116)	(0.095)	(0.115)	(0.107)
Reference: HHINCOME__1					
HHINCOME__2	0.084	0.159**	-0.091	-0.191*	-0.224**
	(0.340)	(0.064)	(0.075)	(0.101)	(0.103)
HHINCOME__3	0.227	0.066	-0.055	-0.115	-0.136
	(0.384)	(0.073)	(0.081)	(0.114)	(0.113)
HHINCOME__4	-0.149	0.162	0.014	-0.114	-0.071
	(0.517)	(0.109)	(0.083)	(0.122)	(0.129)
HHINCOME__5	0.240	0.093	-0.052	-0.348**	-0.350*
	(0.639)	(0.115)	(0.126)	(0.176)	(0.182)
HHINCOME__6	0.296	0.032	-0.006	0.059	0.028
	(0.753)	(0.175)	(0.125)	(0.203)	(0.206)
HHINCOME__7	0.386	-0.077	-0.037	0.191	0.255*
	(0.539)	(0.110)	(0.123)	(0.140)	(0.134)
URBAN_HH	0.133	0.111	0.164	0.059	0.091
	(0.302)	(0.121)	(0.105)	(0.120)	(0.111)
Water, sanitation and hygiene indicators					
IMPROV_DRINK	0.142	-0.065	0.009	0.028	0.036
	(0.339)	(0.097)	(0.083)	(0.112)	(0.108)
Reference: SAN_LADDER _1					
SAN_LADDER_2	0.187	0.055	0.008	0.032	0.083
	(0.420)	(0.085)	(0.063)	(0.088)	(0.087)
SAN_LADDER_3	-0.532	-0.139	-0.034	0.091	0.082
	(0.511)	(0.114)	(0.092)	(0.127)	(0.124)
SAN_LADDER_4	0.857**	0.016	0.142*	0.033	0.093
	(0.390)	(0.100)	(0.080)	(0.102)	(0.103)
LQUDWASTE	0.615**	0.147**	-0.028	-0.198***	-0.174**
	(0.291)	(0.060)	(0.054)	(0.074)	(0.074)
MULTI_DRINK	0.692***	-0.050	-0.035	0.108	0.113
	(0.266)	(0.058)	(0.057)	(0.074)	(0.070)
DRINK_TIME	0.007	-0.000	-0.003	-0.002	-0.003
	(0.009)	(0.002)	(0.002)	(0.002)	(0.003)

Table 2.5 continued

VARIABLES	(1) Diarrhea in the past one month	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Weight-for-height z-score	(5) Body-mass-index-for-age z-score
Multipurpose water systems indicators					
FISHING_HH	0.857*	0.123	-0.054	-0.181	-0.272
	(0.496)	(0.130)	(0.142)	(0.187)	(0.174)
IRRIG_AGRIC	-0.800	0.040	-0.040	-0.035	-0.026
	(1.094)	(0.162)	(0.134)	(0.160)	(0.168)
Interaction terms					
FISHING_HH*IMPROV_DRINK*IRRIG_AGRIC	-0.481	-0.753**	-0.953***	-0.465	-0.389
	(1.582)	(0.357)	(0.342)	(0.395)	(0.381)
FISHING_HH*IMPROV_DRINK	-1.363**	-0.018	-0.020	0.050	0.117
	(0.666)	(0.163)	(0.163)	(0.232)	(0.220)
IRRIG_AGRIC*FISHING_HH	0.394	0.558	1.173***	0.716**	0.721**
	(1.336)	(0.346)	(0.319)	(0.336)	(0.320)
IRRIG_AGRIC*IMPROV_DRINK	0.708	0.060	0.091	0.140	0.093
	(1.168)	(0.185)	(0.173)	(0.208)	(0.215)
Constant	-3.832*	-2.594***	-0.779	0.776	1.985***
	(2.016)	(0.827)	(0.779)	(0.836)	(0.732)
Observations	1,517	1,128	1,126	992	1,113
Number of children	548	466	473	432	472
Prob> chi^2	0.00139	1.59e-08	0.000739	7.62e-05	0

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

2.4.5 Sub-group Analysis

2.4.5.1 Children Under Five Years of Age

In this section, we estimate the determinants of health and nutrition status of children under five years of age (see Tables 2.6 and 2.7). Most commonly in anthropometric literature, children under five years of age are used in regression specifications with indicators of child malnutrition as dependent variables. In order to obtain comparable results with children under eight years of age, the estimates reported in Tables 2.6 and 2.7 use the same variables as shown in Tables 2.4 and 2.5. Regression results for child health and nutrition for children under five years of age that include multipurpose water system and water, sanitation and hygiene determinants along with individual and household characteristics are presented in Table 2.6. Four out of the five reduced form models (except weight-for-height z-score regression result) passes the test of goodness fit with the *P*-value of the Wald test of joint significance (Prob. > chi^2) being less than 5 percent. This means that in the reduced form regression specifications for diarrhea in the past one month, height-for-age z-score, weight-for-age z-score and body-mass-index-for-age *z*-score, the explanatory variables jointly and statistically significantly explain the variation in the dependent variables. Robust standard errors are reported for the regression specifications on anthropometric outcomes. To a large extent, the results obtained here partly confirm those obtained using the full sample of children under eight years of age.

Effects of Other Household Characteristics on Child Health and Nutrition Outcomes

The age dummies indicate that diarrhea decreases for children in the age of 3 and 4 years in comparison with the reference group (0 years of age). In addition, malnutrition increases with age except for weight-for-height z-score where none of the age dummies is statistically significant at the traditional confidence levels. Child holding valid NHIS card is positively associated with diarrhea in the past one month preceding the surveys. Squared of the age of the household head is positively associated with body-mass-index-for-age *z*-score.

Households access to internet and households connected to the national grid are positively associated with weight-for-age z-score. Income of households has no statistically significant effect on diarrhea in the past one month and weight-for-age z-score. However, the household per monthly income in the bracket of GHS 200.1 to GHS 400 compared with the reference group is positively related to height-for-age z-score and negatively related to weight-for-height z-score and body-mass-index-for-age *z*-score. This means household per monthly income differently affect short term and long term nutritional status.

Effects of Water, Sanitation and Hygiene on Child Health and Nutrition Outcomes

Households' use of improved drinking water sources is negatively associated with diarrhea in the past one month preceding the survey. This means that households use of improved drinking water sources decreases the incidence of diarrhea among children under five years of age. Surprisingly, households' access to improved drinking water sources is negatively associated with height-for-age z-score and weight-for-age z-score. Open defecation compared to improved sanitation facilities is positively associated with diarrhea in the past one month preceding the surveys. Unimproved sanitation facilities compared to improved sanitation facilities is negatively associated with height-for-age z-score.

Disposal of liquid waste onto the compound is positively associated with height-for-age z-score and negatively related with weight-for-height z-score. Households having multiple drinking water sources are positively associated with weight-for-height z-score and body-mass-index-for-age *z*-score.

Effects of Multipurpose Water Systems on Child Health and Nutrition Outcomes

Households' participation in irrigated agriculture is positively associated with weight-for-age z-score, weight-for-height z-score and body-mass-index-for-age *z*-score. However, households undertaking fishing has no statistically significant effect on any of the measures for child health and nutrition status among children under five years of age.

Table 2.6: Determinants of Health and Nutrition Status of Children Under Five Years of Age

VARIABLES	(1) Diarrhea in the past one month	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Weight-for-height z-score	(5) Body-mass-index-for-age z-score
Individual or child characteristics					
Reference: AGE_YEARS_0					
AGE_YEARS_1	-0.244	-0.743*	-0.732***	-0.096	-0.463
	(0.434)	(0.441)	(0.269)	(0.491)	(0.473)
AGE_YEARS_2	-0.296	-0.613	-1.046***	-0.220	-0.747*
	(0.422)	(0.390)	(0.276)	(0.459)	(0.440)
AGE_YEARS_3	-0.822*	-0.568	-0.846***	0.136	-0.445
	(0.442)	(0.384)	(0.274)	(0.446)	(0.425)
AGE_YEARS_4	-1.225***	-0.248	-0.894***	-0.228	-0.832**
	(0.450)	(0.375)	(0.271)	(0.439)	(0.414)
BIO_CHILD	-0.486	0.303	0.178	0.049	-0.090
	(0.355)	(0.229)	(0.190)	(0.194)	(0.196)
MALE_CHILD	0.183	-0.114	-0.197	-0.035	-0.036
	(0.271)	(0.141)	(0.126)	(0.142)	(0.142)
CHILD_NHIS	0.970***	-0.046	-0.118	-0.026	0.063
	(0.315)	(0.117)	(0.097)	(0.125)	(0.133)
Parental/household head characteristics					
MALE_HEAD	-0.181	-0.082	-0.183	-0.220	-0.076
	(0.347)	(0.182)	(0.172)	(0.184)	(0.184)
AGE_HEAD	-0.033	0.064	0.020	-0.045	-0.065
	(0.076)	(0.049)	(0.042)	(0.039)	(0.040)
AGE_HEAD_SQ	0.000	-0.001	-0.000	0.001	0.001*
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Reference: EDUC_HH_1					
EDUC_HH_2	-0.169	0.052	0.032	0.116	0.133
	(0.347)	(0.204)	(0.146)	(0.171)	(0.177)
EDUC_HH_3	-0.686	-0.176	0.244	0.240	0.295
	(0.605)	(0.232)	(0.198)	(0.253)	(0.286)
ETHNIC_HEAD	-0.159	-0.093	-0.083	-0.086	-0.063
	(0.300)	(0.163)	(0.142)	(0.153)	(0.160)
Socio-economic characteristics					
EVERTREAT	0.362	-0.038	-0.077	-0.082	-0.065
	(0.277)	(0.137)	(0.120)	(0.131)	(0.140)
INTERNET_HH	-0.249	0.228	0.271**	0.101	0.113
	(0.448)	(0.149)	(0.108)	(0.137)	(0.149)
ELECTRIC_HH	-0.064	0.259	0.353**	0.075	0.087
	(0.341)	(0.182)	(0.145)	(0.161)	(0.163)
Reference: HHINCOME__1					
HHINCOME__2	0.066	0.266**	-0.109	-0.333**	-0.413***
	(0.359)	(0.113)	(0.123)	(0.150)	(0.150)
HHINCOME__3	0.340	0.113	0.001	-0.119	-0.178
	(0.409)	(0.128)	(0.127)	(0.154)	(0.159)
HHINCOME__4	-1.142	0.315	-0.006	-0.230	-0.222
	(0.807)	(0.193)	(0.136)	(0.188)	(0.213)

Table 2.6 continued

VARIABLES	(1) Diarrhea in the past one month	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Weight-for-height z-score	(5) Body-mass-index-for-age z-score
HHINCOME__5	0.447	0.088	0.110	-0.115	-0.182
	(0.644)	(0.206)	(0.165)	(0.239)	(0.258)
HHINCOME__6	0.107	0.032	0.084	0.203	0.132
	(0.872)	(0.330)	(0.200)	(0.304)	(0.323)
HHINCOME__7	0.353	-0.211	-0.167	0.196	0.292
	(0.580)	(0.174)	(0.205)	(0.189)	(0.196)
URBAN_HH	0.429	0.076	0.143	0.151	0.109
	(0.333)	(0.176)	(0.158)	(0.168)	(0.169)
Water, sanitation and hygiene indicators					
IMPROV_DRINK	-0.482*	-0.219*	-0.184*	0.082	0.088
	(0.281)	(0.132)	(0.109)	(0.131)	(0.143)
Reference: SAN_LADDER _1					
SAN_LADDER_2	0.481	-0.042	-0.000	0.138	0.166
	(0.456)	(0.143)	(0.090)	(0.117)	(0.129)
SAN_LADDER_3	-0.633	-0.384**	-0.079	0.204	0.241
	(0.581)	(0.181)	(0.122)	(0.170)	(0.181)
SAN_LADDER_4	0.942**	-0.223	0.122	0.149	0.181
	(0.422)	(0.161)	(0.119)	(0.145)	(0.148)
LQUDWASTE	0.450	0.245**	0.067	-0.211**	-0.187
	(0.319)	(0.104)	(0.084)	(0.105)	(0.116)
MULTI_DRINK	0.460	-0.099	-0.017	0.176*	0.210**
	(0.281)	(0.102)	(0.094)	(0.101)	(0.105)
DRINK_TIME	0.011	0.002	-0.001	-0.001	-0.002
	(0.010)	(0.004)	(0.003)	(0.004)	(0.004)
Multipurpose water systems indicators					
FISHING_HH	0.153	0.089	0.178	0.080	0.047
	(0.333)	(0.107)	(0.117)	(0.121)	(0.127)
IRRIG_AGRIC	-0.314	0.036	0.223**	0.257**	0.249*
	(0.354)	(0.111)	(0.102)	(0.128)	(0.132)
Constant	-1.316	-2.875***	-0.922	0.804	2.043**
	(1.891)	(1.115)	(1.083)	(1.076)	(1.033)
Observations	812	595	601	568	591
Number of children	318	276	283	270	282
Prob> chi^2	0.0239	0.000354	0.0258	0.156	0.0135

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Results with Interaction Terms

Table 2.7 presents regression results including the interaction of indicators of multipurpose water systems and WASH variables for child health and nutrition status for children under five years of age. In Table 2.6, we found that household participation in irrigated agriculture is positively related to weight-for-age z-score, weight-for-height z-score and body-mass-index-for-age *z*-score. In Table 2.7, including the interaction terms makes this variable not statistically significant. The interaction between the three indicators, fishing, irrigated agriculture and improved drinking water sources (FISHING_HH*IMPROV_DRINK*IRRIG_AGRIC) is negatively associated with weight-for-age z-score. This result indicates that the combination of the three indicators may not lead to higher nutritional status as indicated by the statistically significant negative coefficient estimate of the interaction term. However, the interaction between fishing and irrigated agriculture (IRRIG_AGRIC*FISHING_HH) is positively associated with weight-for-age z-score, weight-for-height z-score, and body-mass-index-for-age *z*-score.

Table 2.7: Results with Interaction Terms for Children Under Five Years of Age

VARIABLES	(1) Diarrhea in the past one month	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Weight-for-height z-score	(5) Body-mass-index-for-age z-score
Individual or child characteristics					
Reference: AGE_YEARS_0					
AGE_YEARS_1	-0.250	-0.720	-0.695***	-0.097	-0.472
	(0.438)	(0.449)	(0.254)	(0.494)	(0.478)
AGE_YEARS_2	-0.369	-0.601	-1.032***	-0.235	-0.767*
	(0.428)	(0.397)	(0.262)	(0.464)	(0.447)
AGE_YEARS_3	-0.864*	-0.561	-0.846***	0.113	-0.471
	(0.447)	(0.391)	(0.264)	(0.450)	(0.431)
AGE_YEARS_4	-1.276***	-0.254	-0.913***	-0.251	-0.858**
	(0.456)	(0.379)	(0.261)	(0.443)	(0.421)
BIO_CHILD	-0.505	0.313	0.208	0.062	-0.079
	(0.359)	(0.229)	(0.187)	(0.194)	(0.197)
MALE_CHILD	0.149	-0.111	-0.187	-0.037	-0.037
	(0.272)	(0.140)	(0.123)	(0.142)	(0.142)
CHILD_NHIS	0.905***	-0.028	-0.103	-0.024	0.064
	(0.318)	(0.118)	(0.094)	(0.126)	(0.135)
Parental/household head characteristics					
MALE_HEAD	-0.208	-0.088	-0.201	-0.229	-0.085
	(0.352)	(0.180)	(0.174)	(0.186)	(0.187)
AGE_HEAD	-0.023	0.062	0.019	-0.045	-0.066
	(0.077)	(0.049)	(0.042)	(0.040)	(0.041)
AGE_HEAD_SQ	-0.000	-0.000	-0.000	0.001	0.001*
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Reference: EDUC_HH_1					
EDUC_HH_2	-0.183	0.073	0.043	0.107	0.125
	(0.349)	(0.207)	(0.147)	(0.171)	(0.178)
EDUC_HH_3	-0.644	-0.161	0.222	0.210	0.270
	(0.605)	(0.231)	(0.197)	(0.254)	(0.287)
ETHNIC_HEAD	-0.119	-0.071	-0.051	-0.079	-0.053
	(0.305)	(0.161)	(0.144)	(0.154)	(0.161)
Socio-economic characteristics					
EVERTREAT	0.343	-0.052	-0.125	-0.120	-0.095
	(0.280)	(0.138)	(0.119)	(0.131)	(0.140)

Table 2.7 continued

VARIABLES	(1) Diarrhea in the past one month	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Weight-for-height z-score	(5) Body-mass-index-for-age z-score
INTERNET_HH	-0.249	0.197	0.232**	0.088	0.106
	(0.452)	(0.130)	(0.109)	(0.144)	(0.155)
ELECTRIC_HH	-0.029	0.223	0.297**	0.073	0.087
	(0.348)	(0.189)	(0.135)	(0.164)	(0.167)
Reference: HHINCOME__1					
HHINCOME__2	0.032	0.249**	-0.161	-0.363**	-0.436***
	(0.365)	(0.113)	(0.113)	(0.152)	(0.152)
HHINCOME__3	0.272	0.085	-0.063	-0.143	-0.198
	(0.416)	(0.127)	(0.108)	(0.154)	(0.159)
HHINCOME__4	-1.169	0.302	-0.049	-0.258	-0.241
	(0.811)	(0.188)	(0.126)	(0.188)	(0.212)
HHINCOME__5	0.425	0.086	0.101	-0.110	-0.174
	(0.646)	(0.206)	(0.156)	(0.241)	(0.260)
HHINCOME__6	0.058	-0.003	0.012	0.176	0.112
	(0.877)	(0.335)	(0.199)	(0.309)	(0.327)
HHINCOME__7	0.387	-0.217	-0.182	0.165	0.275
	(0.581)	(0.175)	(0.209)	(0.189)	(0.195)
URBAN_HH	0.487	0.120	0.221	0.182	0.136
	(0.339)	(0.180)	(0.162)	(0.171)	(0.172)
Water, sanitation and hygiene indicators					
IMPROV_DRINK	-0.236	-0.123	-0.022	0.108	0.115
	(0.349)	(0.171)	(0.116)	(0.166)	(0.182)
Reference: SAN_LADDER _1					
SAN_LADDER_2	0.494	-0.018	0.045	0.156	0.182
	(0.458)	(0.144)	(0.088)	(0.120)	(0.132)
SAN_LADDER_3	-0.673	-0.366**	-0.074	0.200	0.236
	(0.587)	(0.182)	(0.123)	(0.174)	(0.185)
SAN_LADDER_4	0.954**	-0.211	0.122	0.152	0.182
	(0.424)	(0.165)	(0.114)	(0.148)	(0.152)
LQUDWASTE	0.434	0.248**	0.047	-0.229**	-0.200*
	(0.321)	(0.103)	(0.081)	(0.105)	(0.116)
MULTI_DRINK	0.490*	-0.110	-0.024	0.179*	0.216**
	(0.282)	(0.102)	(0.092)	(0.099)	(0.104)
DRINK_TIME	0.011	0.002	-0.000	-0.001	-0.002
	(0.010)	(0.004)	(0.003)	(0.004)	(0.004)
Multipurpose water systems indicators					
FISHING_HH	0.587	0.039	0.125	-0.003	0.002
	(0.515)	(0.237)	(0.204)	(0.248)	(0.260)
IRRIG_AGRIC	-0.962	0.115	-0.023	-0.071	-0.038
	(1.095)	(0.283)	(0.202)	(0.204)	(0.232)

Table 2.7 continued

VARIABLES	(1) Diarrhea in the past one month	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Weight-for-height z-score	(5) Body-mass-index-for-age z-score
Interaction terms					
FISHING_HH*IMPROV_DRINK*IRRIG_AGRIC	-0.149	-0.700	-1.131**	-0.624	-0.487
	(1.678)	(0.572)	(0.513)	(0.494)	(0.511)
FISHING_HH*IMPROV_DRINK	-1.162	0.050	-0.207	-0.091	-0.118
	(0.765)	(0.283)	(0.242)	(0.311)	(0.319)
IRRIG_AGRIC*FISHING_HH	0.907	0.548	1.395***	0.901**	0.744*
	(1.350)	(0.560)	(0.473)	(0.408)	(0.428)
IRRIG_AGRIC*IMPROV_DRINK	0.494	-0.159	0.059	0.244	0.219
	(1.222)	(0.304)	(0.252)	(0.263)	(0.290)
Constant	-1.632	-2.913***	-0.984	0.849	2.075*
	(1.932)	(1.123)	(1.069)	(1.103)	(1.063)
Observations	812	595	601	568	591
Number of children	318	276	283	270	282
Prob> chi^2	0.0366	0.000685	0.00594	0.0480	0.0130

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

2.5. Conclusions

We studied the synergetic effects or nexus or trade-offs between multipurpose water systems, and water, sanitation and hygiene practices, and other household characteristics on child health and nutrition status in southern Ghana. In particular, we analyzed the effects of participation in irrigated agriculture and fishing, household use of improved drinking water sources and sanitation based on JMP classification, and household income on diarrhea incidence in the past one month, height-for-age z-score, weight-for-age z-score, weight-for-height z-score and body-mass-index-for-age z-score of children under eight years of age. Sub-group analysis for children under five years of age, which is the most commonly used age category for regressions using anthropometric outcomes as the dependent variables, was also undertaken. We use four waves of data collected between 2014 and 2015 and the results are obtained by applying the random effects econometric strategy in a panel data analysis.

Most findings from this study complement those from previous studies, particularly on the role of child characteristics, water, sanitation and hygiene practices on child health and nutrition status. The main finding from this study is that household's participation in irrigated agriculture is a significant positive explanatory variable of both short run and long run nutritional status of children. The results show that household's participation in irrigated agriculture is positively and significantly associated with weight-for-age z-score, weight-for-height z-score, and body-mass-index-for-age z-score. This implies that current efforts in Ghana and elsewhere on agriculture intensification and diversification through irrigation facilities should be expanded as it has a positive effect on child health and nutrition status. However, the effects depend on the choice of health and nutrition indicator.

The findings to a large extent confirm the long held importance of the role of water, sanitation and hygiene practices on child health and nutrition status. For example, open defecation increases the risk of diarrhea incidence. Household use of improved drinking water sources based on JMP classification has a limited effect on child health and nutrition status in our study settings. Liquid waste disposal on the compound of the dwelling is associated with higher risk of diarrhea incidence and also lower weight-for-height *z*-score and body-mass-index-for-age *z*-score. The results suggest that current global, regional, national and local initiatives on water, sanitation and hygiene practices need to be intensified in order to derive the optimal benefits on child health and nutrition status. The income effects on child health and nutrition status are generally mixed and this requires further research. Thomas *et al*. (1990) argue that the use of current income instead of permanent income measure in studying the determinants of child health and nutrition status may not be appropriate. This is because current income is more susceptible to recent economic shocks and measurement errors compared to permanent income measure.

While this study contributes to the anthropometry literature in terms of the importance of multipurpose water systems, and water, sanitation and hygiene practices, and other household characteristics on child health and nutrition status, the short duration of the study may raise concern on the long run validity of the results. We believe the results obtained are valid based on the advantages of applying random effects model in a panel data analysis instead of, for instance, cross-sectional data analysis. Nevertheless, a study using longer duration of data collection and larger samples may shed additional light on studying the complexities of the determinants of child health and nutrition status. Furthermore, due to limited sample, we are unable to distinguish between the different types of irrigation systems, which may have different consequences on child health and nutrition status. Future research should include different types of irrigation systems such as drip, sprinkler, furrow, etc. which may have different effects.

We also find that the effects of the explanatory variables are not even as they depend on the measure of child health and nutrition status. This should also be of concern to researchers and policy makers in health and nutrition: they should also focus on the multidimensional nature of child health and nutrition status by studying the interactions/nexus between multipurpose water systems, and water, sanitation and hygiene practices, and other household characteristics. The findings from this study are a step forward in the understanding the nexus or interactions between multipurpose water systems (particularly, participation in irrigated agriculture and fishing), and water, sanitation and hygiene practices, and other household characteristics on child health and nutrition status.

Chapter 3. The Impacts of Household Water Quality Testing and Information on Safe Water Behaviors: Evidence from a Randomized Experiment in Ghana

3.1 Introduction

Worldwide, inadequate access to improved drinking water sources affects about 663 million people, with sub-Saharan Africa accounting for about 50 percent of the population without access to safe water sources (UNICEF and WHO, 2015). According to Bain *et al*. (2014), drinking water sources for about 1.8 billion people worldwide suffer from fecal matter contamination, rendering the water unsafe for human consumption. Furthermore, several water sources considered to be "improved" (based on WHO/UNICEF criteria) are not good for consumption.

In many developing countries, provision of water is mainly regarded as public good while many water resources are usually considered as common property resources (Kremer *et al.* 2011), thereby shifting the burden of water quality testing and information to providers (or state actors) rather than consumers (or private individuals and households). However, a major challenge to the provision of improved water sources to householders is the potential of recontamination during water collection, transportation and handling from point of source (POS) to point of use (POU). This, therefore, requires additional efforts from water users (both individuals and households) in ensuring the safety of water for both drinking and general purposes through behavioral changes. Furthermore, "formal" household water quality testing is virtually non-existent in many developing countries including Ghana, with many households relying on the physical properties (or traditional approaches) including color or odor of the water as indicators of the quality of drinking and general purpose water while others also use visual (or ocular) method to determine the quality of drinking and general purpose water. These approaches are not only insufficient but they are not reliable ways of identifying polluted or contaminated water because these contaminants are mostly not visible to the eyes, which require some form of "formal" water quality testing to identify the type of contaminants present or absent in a given water sample.

The study examines whether water quality testing and information can increase safe water behaviors such as choice of improved water sources, covering of storage water containers, and satisfaction with water quality among households in southern Ghana. Specifically, households in southern Ghana were randomly allocated to participate in water quality self-testing and received information in the form handouts on water quality improvement techniques.

This study relates to other works and makes several contributions to literature. First, the study uses data from four rounds (waves) of household surveys (through in-depth structured interviews) to assess the potential effects of household water quality testing and information on a variety of household safe water behavior changes. The analysis techniques introduce robustness and sensitivity checks to obtain valid estimates. Furthermore, the study becomes more important based on the household use of multiple drinking and general purpose water sources, which is among the least researched areas in terms of both water quantity and quality issues.

Second, the study is related to growing literature on water quality improvement and its effects on household health outcomes and WASH behavior changes. Devoto *et al*., (2012) shows that "information and facilitation drive" on household private tap water connection leads to improvement in well-being/welfare, even though there may be no health and income improvements. In Günther and Schipper (2013), the provision of safe water storage and transport containers leads to improvement in water quality and health outcomes (decrease in diarrheal diseases). Kremer *et al*., (2011) studied the impact of spring protection on water quality and health outcomes. They show that spring protection leads to a reduction in diarrheal diseases and improvement in water quality. Water quality information to households is known to improve WASH behaviors (Madajewicz *et al*., 2007; Hamoudi *et al*., 2012; Jalan and Somanthan, 2008). But a systematic review by Lucas *et al.*, (2011) suggested that despite several studies on water quality testing and dissemination of drinking water contamination data to households, rigorous impact evaluation studies are needed. This study fills this gap in the literature.

Third, this study contributes to the growing literature on water quality testing and information and its effects on household and individual health outcomes and WASHES behavior changes. We provide what to the best of our knowledge the first study to apply multiarm randomized evaluation to study the heterogeneous impacts of household water quality testing and information on safe water behavior changes. Being the first (based on our knowledge) to apply multiarm randomized evaluation of household water quality testing and information, we are able to compare the impacts based on gender (male versus female) of participants and type of household member (children versus adults). None of the previous studies analyze the channels for the delivery of water quality information. In addition, the study used on-field water testing kits (Aquagenx's Compartment Bag Test (CBT)) which quantify the level of fecal contamination of a given water sample. This is an improvement on previous studies (e.g. Brown *et al*., 2014; Madajewicz *et al*., 2007; Hamoudi *et al*., 2012; Jalan and Somanthan, 2008) that used presence or absence test kits. The study design is based on water quality self-testing and recording of results at the household level. This is an addition to literature since previous studies were based on water quality testing and dissemination of information by field assistants.

Finally, we contribute to current literature and discussions on the need for microbial monitoring of water quality as indicated by the United Nations Post-2015 Sustainable Development Goals (SDGs), providing evidence on the practical ways (or learning experiences) of achieving such monitoring framework in resource poor settings.

The study being the first (based on our knowledge) to apply cluster-randomized evaluation design to evaluate intra-household decision making or resource allocation on water quality testing and information, the data allow us to analyze the impacts on safe water behaviors based on school children versus adults and male versus female. The major finding of the study is that intra-household decision making or resource allocation matters when it comes to dissemination of information on water quality: In the study settings freely given water quality test kits and information on water quality generate different uptake rates. The uptake rate is higher for school children compared to adult household members. Also, the uptake rate is slightly high for females compared with males. Despite different uptake rates, the study finds that water quality testing and information increase the choice of improved water sources and covering of stored drinking water, while there is a reduction in satisfaction with water quality and distance taken in collecting water. In most of the outcomes, the study finds that school children were more effective than adults were; indicating that school children could be used as "agents of change" in improving safe water behaviors. However, the study finds limited treatment effects based on the gender of participants.

The study is organized as follows. Section 3.2 describes the water quality testing and information experiment, and data. Section 3.3 presents the impacts of the intervention on safe water behaviors. The section also presents the estimation strategy in analyzing the water quality testing and information experiment impacts. Section 3.4 draws conclusions.

3.2. Water Quality Testing and Information Experiment, and Data

This section describes the water quality testing and information experiment, allocation into treatment and comparison groups, data collection and attrition.

3.2.1 Water Quality Testing and Information Experiment

AG-WATSAN Nexus Project

The AG-WATSAN Nexus project, Ghana is a subset of a broader project implemented by Center for Development Research (ZEF) of the University of Bonn in collaboration with project partners in four countries (Ethiopia, Bangladesh, India, and Ghana). The Ghana project was implemented in conjunction with Institute of Statistical, Social and Economic Research (ISSER) of the University of Ghana, Legon. The Ghana project fits into the main thematic area of the project, which is investigating the linkages and synergies between agriculture, and water, sanitation and hygiene. The Ghana component was mainly an experimental study involving school children and adult household members on how water quality self-testing and information could improve household WASH behaviors and water quality. The study also looked at the potential benefits in terms of health outcomes as measured in diarrhea rates reduction and impact on children health (through anthropometric measurements). The AG-WATSAN Nexus Project, Ghana allowed participants to undertake water quality self-testing and use their experiences in household water management. The project performed key activities such as encouraging households to get involved in water quality testing and using the information in managing household water, providing training on water quality testing including water sample collection, delivery of portable water testing toolkits (Aquagenx's CBT) and water testing results diary/score sheets. Water quality improvement messages in the form of handouts were distributed to participants. Finally, the project also provided a platform to discuss water quality information after water quality testing training programs.

Water Quality Testing and Information Experiment Design

List of eligible participants was compiled from the household listing/tracking data obtained in March 2014 and baseline household data completed in April-May 2014. Participants in the water quality testing and information treatment arms were first informed of their selection and explanations were provided about the water quality testing intervention using the Aquagenx's CBT through the school teacher in charge of the project at the public basic school level. The project was explained to the understanding of the participants as a joint study between ZEF and ISSER to help households improve their WASH environment, and understand WASH issues in rural and urban areas in Greater Accra region. Four main design decisions were made in regard to the water quality testing and information experiment: type of water test kits, the number of test kits per participant, training approach and timing, and personnel to be hired. The type of water test kits was Aquagenx's CBT. This test kit fits the study since it allowed us to quantify the level of *E. coli* in a given water sample. We decided against using the present and absent test kits due to the potential of false predictions/results.

For the number of test kits per participant, it was decided that the number would be fixed at two per participant. This was done to allow participants to perform the water quality self-testing using different water sources available to the households. Furthermore, households rely on multiple water sources for drinking and general purposes, and also factoring in the cost of the test kits, we decided that two test kits per participant would be enough for the water quality self-testing. In relation to training approach and timing, we decided to use a group based training procedure for the experiment, which was deemed more cost-effective than individualize (door-to-door) delivery. Association with other participants (for instance participation together with other community members) could serve as a catalyst for active involvement in the study. The group based approach presents practical lessons since the provision of the experiment free of charge will not automatically mean that everyone will take it. Individualize delivery approach assumes that providing the intervention to the households free of charge means everyone will automatically take the intervention. Distance and time constraints could serve as an additional barrier to participation in the water quality testing and information and this is largely ignored by individualize delivery approach.

Due to logistical and administrative challenges, the first round experiment (period one experiment) had to be made in two phases. The first phase was the training on the use of water testing kits, and the second phase involved water quality self-testing by the participants using their own water sources. The training workshops/sessions were organized at a selected date and time (in consultation with the public basic school authorities) during the first to third week of July 2014. The timing was done in consultation with school authorities since the schools played two important roles: (1) use of school children as one of the treatment arms and in order not to disrupt academic exercises, (2) schools served as a venue for the training workshops. The training workshops employed a variety of teaching and learning methods which included presentations, plenary discussions, and group work, among others. The training workshops, therefore, applied experiential learning approaches with limited formal training. This improved the knowledge and understanding of participants on the activities of water quality testing and information intervention. The training workshops were based on demonstration (practical sessions) with the distribution of water test kits for group-based practical sessions. The training workshops also included water sample collection. The training workshops were undertaken in the various local languages, under the close supervision of the ZEF/ISSER survey team. Each intervention group met twice for about one hour to one and half hours for the training workshops. The first meeting was for the initial water quality testing, with second meeting used for recording of results and discussions on the steps to improve water quality at the household level.

The second phase of the period one experiment involved the delivery of water test kits and households performing water quality self-testing. The water test kits were delivered in the second week of October 2014 (three months after the training workshop). Water quality improvement messages (information) in the form of hand-outs (available upon request) were also distributed to the participating households. Each household was given two copies of the hand-outs for reference and discussions with other household members. The hand-outs containing the water quality improvement messages were designed using messages from previous studies such as Brown *et al,* (2014) and Hamoudi *et al,* (2012). The water quality self-testing was done at the convenience of the participants and recording of results made on a sheet/diary provided by the study team. Participants in the adult household members intervention group were notified to submit results, through the contact person (selected pupil) to the school teacher in charge of the project at the public basic school, while participants in the school children intervention group submitted the results directly to the school teacher. Following Karlan *et al*., (2014) the study did not impose strict compliance on when to test the water and to submit results since we could not control participant’s behavior. Participants were given a flexible time frame (for example one week period) for completion of water testing and submission of test results. This was made flexible as possible, by extending the submission date for some of the treatment arms.

Finally, we decided to use health officers (specifically community health nurses) for the training workshops. The community health nurses were chosen because of their experience in performing community outreach programs on health behaviors. Two days' training session using a well-designed training protocol (available upon request) was held for community health nurses in order to familiarize themselves with the water quality testing and information experiment. Here three female community health nurses (based on availability) were hired to undertake this task. To avoid ethical issues, community health nurses on annual leave were employed for the task. The community health nurses were supported by one project staff to undertake the training exercise. Two teams (made of two persons each) were formed for the training workshops (one team for each of the two study districts). Monitoring and supervision were undertaken periodically to ascertain the performance of the hired community health nurses.

The second round of the intervention (period two experiment) was undertaken in the second week of March 2015, after the completion of third round of household survey. Hired field assistants delivered water quality improvement messages (information) to the participants of the first phase of the intervention. The water quality improvement messages were the same ones used during the first round (period one experiment) of the water quality testing and information experiment. For the adult household members intervention group, we employed individualize delivery (which was more practical) by visiting the participating households. In the case of school children intervention group, we used the group based approach where the students were assembled in their respective public basic schools for the exercise. Each participant was then given two copies of the handout containing the nine water quality improvement messages for reference and discussions with other household members.

Due to costs and time constraints, we could not randomize the water quality testing and information experiment to test the effect of using different options on the type of test kits, a number of test kits per participant, training approaches and timing, and also the type of personnel hired for the training exercise. These are some of the areas for future research. For instance, what are the tradeoffs between using individualize delivery versus group-based approach, and imposing strict compliance of training schedules and delivery of test results versus voluntary attendance of training schedules and flexible compliance on the delivery of test results.

3.2.2 Sample Frame and Randomization of Water Quality Testing and Information Experiment

In order to obtain a representative sample frame for the water quality testing and information experiment, we applied a variety of sampling techniques. The sample design takes into consideration the inclusion criteria in choosing the study setting such as the use of unimproved water systems and sanitation services, and being located in the multipurpose water system. This was to achieve the overall aim of the AG-WATSAN Nexus project of understanding the linkages between agriculture, and water, sanitation and hygiene. In order to obtain the required preliminary data on households, an institutional survey (data collection exercise using designed questionnaires) was conducted in public basic schools, and water and sanitation (WATSAN) committees in the two selected districts (Shai-Osudoku district and Ga South Municipal) in the Greater Accra region of Ghana. This was done to understand the existing WASH situations in the localities and to identify communities located in the multipurpose water system. The WATSAN committee survey, which was a community survey together with public basic schools data, therefore represent the initial sample frame.

The initial stage of the data collection exercise (institutional survey) yielded interviews with 35 WATSAN committees and 48 public basic schools. The public basic schools and WATSAN committees data collection exercise were conducted during the second week of December 2013 by Center for Development Research (ZEF) of University of Bonn, Germany in collaboration with Institute of Statistical, Social and Economic Research (ISSER) of University of Ghana, Legon. During the public basic school survey, we obtained the school register for pupils from grade five to eight. This represents a student population of 4651 from the 48 public basic schools interviewed. Eligibility criteria for the participating public basic schools required that there is both primary and junior high school located in the same compound. Further, the study targeted school children in the upper primary (grade 5-6) and junior high (grade 7-8). Grade 1-4 students might be too young to undertake water quality testing. This was the main reason for their exclusion from the study. Grade 9 school children were dropped from the study due to potential “loss” of participants after completion of basic education certificate examination (BECE). Upon basic school completion, some might migrate to other communities, which might be difficult to track during survey periods.

The baseline household survey was based on cluster random sample (preferably multistage cluster random sample), with a random selection of students to represent the households based on sampled public basic schools. From the institutional data (initial sample frame), communities and public basic schools were selected from the study sites based on the existence of multipurpose water system, and dependent on unimproved water and sanitation services, and then within each public basic school, we selected pupils (who represented the households). The sampling procedure using STATA software takes into consideration the grade and gender of the student.

Upon completion of sampling, a household tracking/listing exercise was undertaken in March 2014 to identify all the selected students and their respective households. Selected siblings from the same households were replaced with students from different households from the same school, grade, and gender. During the baseline household data collection, within each selected household, the household head or individuals (for instance, spouse) who are knowledgeable in WASH practices were interviewed. Other criteria for individuals interviewed included those who usually make decisions on household WASH. In addition, selected pupils were also interviewed on WASH knowledge and practices at individual and household levels (only limited to school children intervention arm during period one experiment). In all, the sample design yielded a total household sample of 512 (i.e. 32 students per 16 selected public basic schools). This represents the sample frame for the baseline household data collection used for the water quality testing and information experiment.

The study involves water quality testing and information delivered to the two treatment arms; (1) school children intervention group and (2) adult household members intervention group. The 512 households were randomly allocated into one of the two experimental blocks by equal proportions (to achieve balance design): 256 water quality testing and information and 256 to the comparison group (no water testing and no information). In the case of 256 participants for the water quality testing and information experiment, the total number of participants was separated into equal proportions of males and females, and also adult household members and students. This is to identify the most effective channel for WASH information delivery. Here there were 128 adult household members and 128 students. This was further apportioned as 64 boys and 64 girls for the students, and 64 males and 64 females for the adult household members. In order to achieve balance in the gender of participants for the adult household members, selected males students were to be represented by their fathers or male guardians while the female students were to be represented by their mothers or female guardians. Since not all selected parents/guardians would be available for the experiment, we allowed the selected households to delegate. The delegate was to be of the same gender of the selected students. This makes the reference to this intervention as adult household members intervention group instead of parents/guardians intervention group (refer to Appendix Table A1, and Figure 3.1 for the sample frame, randomization design and timelines for the experiment).

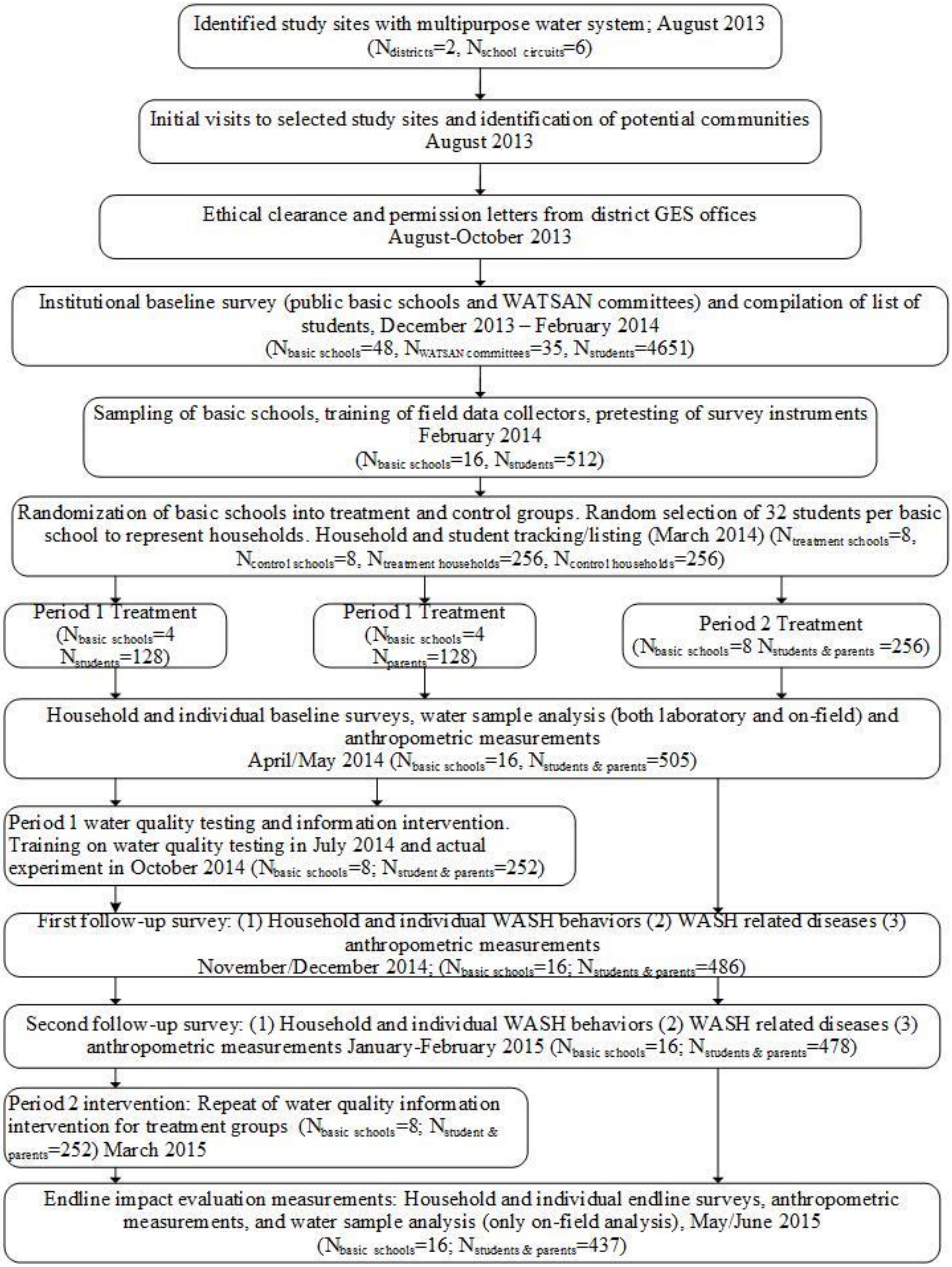
There are mainly two types of randomization for impact evaluation of WASH-related interventions involving schools and school children. These are (1) within-school randomization designs and (2) across-school randomization designs. These two approaches differ in scope, objectives of the study and its application. Within-school randomization design is essential in identifying “peer effects” but its major weakness is that it could limit the “true” size of the effects/impacts of the interventions due to contamination. According to Miguel and Kremer

(2004), within school randomization designs on worms prevention affects the possibility of objectively analyzing spillover effects. Miguel and Kremer (2004) further highlighted that "across pupils within schools" randomization is essential in using experimental procedures in analyzing the main effects of intervention schools into both "direct effect and within-school externality effect". One way of dealing with contamination is through blinding of the respondents or interventions. While across school randomization design is helpful in limiting the potential sources of contamination of the control groups, other factors such school and household characteristics cannot be controlled, especially in smaller sample studies.

The study applies cluster-randomized evaluation design. Due to within-school interactions between school children and teachers, the study's unit of randomization is the public basic school while the unit of analysis is at the individual and household level. Therefore, households stratified by the community and public basic school (unit of randomization) were assigned to the treatment arms. Randomization was conducted anonymously and it was undertaken by a third party (the so-called third party randomization) with no interest or whatsoever in the study. Furthermore, the baseline household data obtained was used to verify the randomization process by performing the mean orthogonality tests based on observable attributes/covariates across the treatment arms. Participants were "blinded" as much as possible in terms of details of intervention to avoid them knowing what other groups were doing. Furthermore, selected public basic schools were far apart (at least 3 kilometers apart) to limit interaction between the treatment and comparison groups. This means conscious effort was made not to leak too much information concerning the study locations and treatment arms. The experiment was presented to the participants as a research study between ZEF and ISSER, and also community and school WASH awareness program.

Summary (descriptive) statistics based on a comparison of means of each treatment block to the control group (for instance, use of t-test or *p-value*) and also F-test for regressions based on the covariates in the treatment blocks was undertaken. The regression of the covariates on the various treatment blocks was undertaken to ascertain the randomization process and imbalances by identifying statistically significant variables across the allocation of treatment arms (see Karlan *et al*., 2014; Devoto *et al*., 2012 and Kremer *et al*., 2011 for more information).

Figure 3.1: AG-WATSAN Nexus Project Timeline, 2013-2015



3.2.3 Data Collection

The study (including consent and assent form) has ethical approval from Ethics Committee of Center for Development Research as well as the Noguchi Memorial Institute for Medical Research (NMIMR), Ghana. At NMIMR, the study is registered as NMIMR-IRB CPN 017/13-14 and Federalwide Assurance FWA 00001824. The study also had written permission letters from the two district Ghana Education Service (GES) offices.

The study relies mainly on one data source: (1) household survey data. The household survey data have been collected on a wide range of variables on the households and their respective members through structured interviews and in the case of children under eight years, anthropometric measurements. The household survey data was conducted in four different time periods (survey rounds) making it possible to estimate both short-run and medium term impacts of the water quality testing and information experiment. The survey rounds have a quarterly timeframe. It should be noted that the timeframe was not strictly quarterly due to logistical and administrative constraints. The baseline household survey yielded 505 household interviews, a success rate of 98.6 percent.

The second round of household data collection (i.e. first follow-up survey) in November/December 2014 yielded 486 household interviews (with attrition rate been 3.76 percent). The third round of household data collection (i.e. second follow-up survey) in January/February 2015 resulted in interviews with 478 households (an attrition rate of 5.35 percent). The second phase of the experiment was undertaken in the second week of March 2015. This was a repeat of the water quality improvement messages used for the period one experiment. The fourth round of data collection (i.e. endline survey) was undertaken in May-June 2015. We completed 437 out of 505 surveys for fourth round survey for an overall success rate of 86.53 percent. In total, there were 1,906 households in the four rounds of data collection. About 87.30 percent of the households were enumerated in all the four survey rounds, 11.49 percent in three, 0.73 percent in two and finally, 0.47 percent in only one. The data analysis for this study relies on households with baseline data and at least one follow-up data.

Table 3.1: Observational Counts and Attrition

Surveys	**Baseline Survey (Round one)**	**First Follow-up (Round Two)**	**Second Follow-up (Round Three)**	**Endline Survey (Round Four)**
Targeted	512	505	505	505
Completed	505	486	478	437
Variation	7	19	27	68
Percent of variation (Attrition)	**1.37**	**3.76**	**5.35**	**13.47**

3.2.4 Baseline Summary Statistics and Orthogonality Tests

Table 3.2 presents baseline descriptive statistics and mean orthogonality tests for household safe water behaviors and socioeconomic characteristics. The baseline summary statistics and mean orthogonality tests draw heavily on approach by Karlan *et al*., (2014). For a complete analysis, we perform the analyses for all households having baseline information irrespective of whether the households completed the subsequent follow-up surveys. In Table 3.2, we present the comparison of means between each of the treatment arm to the comparison group, an *F-test* from separate regression of each outcome variable on the two treatment arms (column 5), and an *F-test* from a regression of all the covariates on each of the study arm (last but one row of each table). The *F-test* presents a test for the overall difference in study arms as a whole for each outcome variable. The *F-test* shows whether large differences exist in the covariates between the study arms. The weakness of the *F-test* is if statistically significant difference is detected in covariates (i.e. P-value<10 percent) across the treatment arms, we cannot determine which study arm is different from another. In order to address this weakness in *F-tests*, we perform separate analysis (available upon request) based on pairwise comparisons of each outcome variable for the treatment and control groups. Furthermore, in the baseline analysis and subsequent analysis, we combine the two control groups (i.e. school children and adult household members control groups) as a comparison group. This is essential in comparing the means of the study arms. In the baseline analysis, we analyze the *F-tests* (column 5) with regressions excluding the comparison group. Obviously, STATA software will drop one of the study arms in the *F-tests* and we deliberately selected the comparison group, to serve as the basis of comparison for the intervention arms. The standard errors are adjusted for clustering at the public basic school level. By not clustering the standard errors at the public basic school level, we find that some of the covariates are statistically significantly different from zero. We address this bias by running separate regressions for all outcome variables including baseline household and basic school covariates (results with even number columns under the impacts sub-section). This is expected to deal with any bias (both observed and unobserved) during data collection and randomization.

The mean tests show no statistically significant difference between the study arms under baseline household composition and socioeconomic characteristics (Table 3.2, panel A). Most baseline household head characteristics and multipurpose water characteristics are similar across the treatment and comparison groups (Table 3.2, panels B and C). The *F-test* shows largely statistically insignificant differences between these outcomes across the treatment and comparison groups. The same results are found under the safe water behaviors sub-sections. Treatment and comparison groups have homogeneous sources of drinking water as well as water transport, handling and storage practices, and water consumption and security issues (Table 3.2, Panels E-H).

Average household size is about six. Approximately two female children under age 15 reside in the average household. The majority of the households have electricity through the national grid (about 76 percent). The household heads are relatively old with an average age of 49 years. Literacy of the household heads is moderately high with about 41 percent reporting of being able to read and write in English. Most of the households reside in the locality with multi-purpose water systems. About 45 percent of the households reside in localities with irrigated fields. About 25 percent of the households participate in irrigated agriculture while about 16 percent of the households participate in fishing. Access to improved water supply is fairly high compared to many rural areas in Ghana as about 73 percent of the households rely on improved main drinking water sources based on WHO's joint monitoring program (JMP) classification. Water sources are far from the households as households spend on average 12.35 minutes traveling to and from main drinking water source. The mean of household water treatment by any means is about 12 percent. Water storage behavior is fairly high as 91.5 percent of the households have stored water in covered containers. In general, the households in the intervention and comparison groups are similar to many of the covariates. Out of a total of 73 *F-tests* performed, 10 were statistically significantly different from zero at the various confidence levels. This was largely influenced by the variations in water quality, treatment and health risk indicators at the household level (Table 3.2, Panel D) which represent about 40 percent of those variables indicating statistically significant different from zero.

Table 3.2: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel A: Household composition and socio-economic status					
Household size	6.083	6.056	5.976	6.150	**0.156**
	(0.113)	(0.225)	(0.246)	(0.153)	**(0.857)**
Number of female members 15 years or older	1.848	1.824	1.843	1.862	**0.048**
	(0.050)	(0.096)	(0.105)	(0.071)	**(0.953)**
Number of female children under 15 years	1.210	1.344	1.189	1.154	**0.916**
	(0.048)	(0.098)	(0.093)	(0.068)	**(0.421)**
Household has electricity	0.764	0.832	0.776	0.724	**2.169**
	(0.019)	(0.034)	(0.037)	(0.028)	**(0.149)**
Household resides in Ga South Municipal (1=Urban district, 0=Shai-Osudoku)	0.499	0.496	0.496	0.502	**0.000**
	(0.022)	(0.045)	(0.045)	(0.032)	**(1.000)**
Value of household annual expenditure (GHS)	6,503	5,926	6,133	6,974	**0.876**
	(206.200)	(308.000)	(405.700)	(321.800)	**(0.437)**
Value of household assets (GHS)	30,917	27,726	28,173	33,870	**0.192**
	(3,109)	(5,436)	(4,848)	(5,044)	**(0.827)**
F-test (p-value) from regression of each study arm on all above covariates		**0.778**	**0.847**	**2.116**	
		(0.615)	**(0.567)**	**(0.106)**	
Observations (N)	**505**	**125**	**127**	**253**	

Notes. Clustered standard errors are presented in parenthesis. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 28 tests in total for household composition and socioeconomic characteristics.

Table 3.2: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey) (continued)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel B: Head of the household					
Head is a male	0.743	0.696	0.803	0.735	**3.626***
	(0.020)	(0.041)	(0.035)	(0.028)	**(0.0519)**
Head's age (Years)	48.81	47.82	48.31	49.56	**0.815**
	(0.556)	(1.088)	(1.119)	(0.791)	**(0.461)**
Head is married	0.688	0.720	0.764	0.635	**1.970**
	(0.021)	(0.040)	(0.038)	(0.030)	**(0.174)**
Head can read and write in English	0.408 (0.0220)	0.407 (0.0445)	0.432 (0.0445)	0.396 (0.031)	**0.139** **(0.871)**
Farming is current primary occupation of the household head	0.501 (0.022)	0.472 (0.045)	0.551 (0.044)	0.490 (0.032)	**0.179** **(0.838)**
Head's Christian	0.778	0.760	0.738	0.806	**0.339**
	(0.019)	(0.039)	(0.039)	(0.025)	**(0.718)**
Head is Ga/Adangbe ethnic group	0.445 (0.022)	0.488 (0.045)	0.344 (0.043)	0.474 (0.032)	**0.543** **(0.592)**
F-test (p-value) from regression of each treatment assignment on all above covariates		**1.133** **(0.394)**	**0.897** **(0.533)**	**2.528*** **(0.062)**	
Observations (N)	**505**	**125**	**127**	**253**	

Notes. Standard errors are presented in parenthesis. The standard errors are adjusted for clustering at the public basic school level. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 28 tests in total for household head characteristics.

Table 3.2: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey) (continued)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel C: Multipurpose water systems, irrigated agriculture, and fishing characteristics					
Presence of irrigated fields in the community	0.452	0.400	0.535	0.434	**0.387**
	(0.022)	(0.045)	(0.044)	(0.031)	**(0.686)**
Household participates in irrigated agriculture	0.253	0.136	0.402	0.237	**2.427**
	(0.019)	(0.031)	(0.044)	(0.027)	**(0.122)**
Presence of fishing waters in the community	0.730	0.774	0.774	0.685	**0.318**
	(0.020)	(0.038)	(0.038)	(0.030)	**(0.733)**
Household has access to fishing waters	0.626	0.645	0.642	0.607	**0.043**
	(0.022)	(0.043)	(0.043)	(0.031)	**(0.958)**
Household engage in fishing	0.159	0.112	0.216	0.154	**0.795**
	(0.016)	(0.028)	(0.037)	(0.023)	**(0.470)**
F-test (p-value) from regression of each treatment assignment on all above covariates		**1.100**	**1.964**	**0.896**	
		(0.401)	**(0.143)**	**(0.509)**	
Observations (N)	**505**	**125**	**127**	**253**	

Notes. Clustered standard errors are presented in parenthesis. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable of interest. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 20 tests in total for multipurpose water systems characteristics.

Table 3.2: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey) (continued)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel D: Water quality, treatment, and health risk					
Main drinking water source is dirty	0.127	0.065	0.159	0.142	**7.671*****
	(0.015)	(0.022)	(0.033)	(0.022)	**(0.005)**
Main general purpose water source is dirty	0.207	0.121	0.206	0.250	**3.056***
	(0.018)	(0.029)	(0.036)	(0.027)	**(0.077)**
Satisfied with water quality	0.648	0.758	0.452	0.692	**6.956*****
	(0.021)	(0.039)	(0.045)	(0.029)	**(0.007)**
Household treat water to make it safer to drink	0.120	0.0820	0.146	0.127	**0.730**
	(0.015)	(0.025)	(0.032)	(0.021)	**(0.498)**
F-test (p-value) from regression of each treatment assignment on all above covariates		**1.539**	**1.834**	**1.261**	
		(0.241)	**(0.175)**	**(0.328)**	
Observations (N)	**505**	**125**	**127**	**253**	

Notes. *** p<0.01, ** p<0.05, and * p<0.1. Standard errors are presented in parenthesis. The standard errors are adjusted for clustering at the public basic school level. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable of interest. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 16 tests in total for water quality, treatment, and health risk indicators.

Table 3.2: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey) (continued)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel E: Water source choices					
Improved main drinking water source (based on JMP classification)	0.731 (0.02)	0.696 (0.041)	0.669 (0.042)	0.779 (0.026)	**0.993** **(0.393)**
Other improved (based on JMP drinking water ladder)	0.659 (0.02)	0.608 (0.044)	0.669 (0.042)	0.680 (0.029)	**0.075** **(0.928)**
Unimproved sources (based on drinking water ladder)	0.109 (0.01)	0.208 (0.036)	0.110 (0.028)	0.059 (0.015)	**0.487** **(0.624)**
Surface water (based on drinking water ladder)	0.160 (0.02)	0.096 (0.027)	0.220 (0.037)	0.162 (0.023)	**1.551** **(0.244)**
Multisource user_**drinking water**	0.392 (0.02)	0.408 (0.044)	0.307 (0.041)	0.427 (0.031)	**1.735** **(0.210)**
Multisource user_**general purpose water**	0.420 (0.02)	0.480 (0.045)	0.291 (0.041)	0.455 (0.031)	**5.785**** **(0.014)**
Improved **secondary** drinking water source	0.677 (0.033)	0.745 (0.062)	0.590 (0.080)	0.676 (0.045)	**0.755** **(0.487)**
Improved **main** general purpose water source (JMP classification)	0.586 (0.022)	0.552 (0.045)	0.591 (0.044)	0.601 (0.031)	**0.048** **(0.953)**
Main drinking water is sachet/bottle	0.147 (0.016)	0.192 (0.035)	0.126 (0.030)	0.134 (0.022)	**0.150** **(0.862)**
F-test (p-value) from regression of each treatment assignment on all above covariates		**1.302** **(0.314)**	**1.266** **(0.330)**	**1.501** **(0.240)**	
Observations (N)	**505**	**125**	**127**	**253**	

Notes. *** p<0.01, ** p<0.05, and * p<0.1. Standard errors are presented in parenthesis. The standard errors are adjusted for clustering at the public basic school level. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable of interest. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 36 tests in total for water source choices. Note that improved secondary drinking water source is dropped from the analysis in the last but one column since not all households have secondary drinking water source.

Table 3.2: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey) (continued)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel F: Water transport, collection, and handling techniques					
Distance to main drinking water (one way, in meters)	197.9 (13.69)	138.9 (21.11)	262.4 (32.28)	195.2 (19.13)	**4.725**** **(0.026)**
Distance to main general purpose water (one way, in meters)	225.6 (14.35)	165.3 (24.67)	240.4 (27.22)	248.3 (21.91)	**3.572*** **(0.0538)**
Time to main drinking water source (round trip, in minutes)	12.35 (0.539)	9.811 (0.774)	15.56 (1.435)	11.99 (0.682)	**3.805**** **(0.046)**
Time to main general purpose water source (round trip, in minutes)	12.88 (0.491)	11.09 (0.876)	13.18 (0.899)	13.60 (0.751)	**0.809** **(0.464)**
Children under 12 years fetch water	0.418 (0.023)	0.411 (0.047)	0.409 (0.046)	0.425 (0.032)	**0.078** **(0.926)**
F-test (p-value) from regression of each treatment assignment on all above covariates		**1.080** **(0.401)**	**3.065**** **(0.050)**	**1.443** **(0.268)**	
Observations (N)	**505**	**125**	**127**	**253**	

Notes. *** p<0.01, ** p<0.05, and * p<0.1. Clustered standard errors are presented in parenthesis. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable of interest. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 20 tests in total for water transport, collection and handling techniques. Note that children under 12 years fetch was dropped for the F-test of all covariates on each treatment assignment due to limited observation.

Table 3.2: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey) (continued)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel G: Water quantity and consumption/usage					
Volume (liters) of drinking water consumed (past 2 days)	81.75	81.27	75.25	85.20	**0.329**
	(3.437)	(6.833)	(5.025)	(5.403)	**(0.724)**
Volume (liters) of general purpose water consumed (past 2 days)	247.3	244.4	240.3	252.2	**0.410**
	(6.380)	(13.00)	(13.11)	(8.839)	**(0.671)**
F-test (p-value) from regression of each treatment assignment on all above covariates		**0.029**	**0.329**	**0.376**	
		(0.972)	**(0.725)**	**(0.693)**	
Observations (N)	**505**	**125**	**127**	**253**	

Notes. Standard errors are presented in parenthesis. The standard errors are adjusted by clustering at the public basic school level. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable of interest. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 8 tests in total for water quantity and consumption/usage.

Table 3.2: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey) (continued)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel H: Water storage behaviors					
Usually stock drinking water in the house	0.853	0.852	0.863	0.848	**0.007**
	(0.016)	(0.032)	(0.031)	(0.023)	**(0.993)**
Container is set on the ground	0.691	0.667	0.708	0.695	**0.065**
	(0.023)	(0.047)	(0.044)	(0.032)	**(0.938)**
Container closed by a lid or cork	0.912	0.942	0.917	0.896	**0.810**
	(0.014)	(0.023)	(0.027)	(0.021)	**(0.463)**
Used soap or detergent to wash container the last time	0.648	0.621	0.704	0.633	**0.493**
	(0.023)	(0.048)	(0.044)	(0.033)	**(0.620)**
Used only plain water in washing the container	0.337	0.350	0.287	0.357	**0.453**
	(0.023)	(0.047)	(0.044)	(0.033)	**(0.644)**
Drinking water storage container is covered	0.915	0.902	0.966	0.898	**0.862**
	(0.013)	(0.027)	(0.017)	(0.020)	**(0.442)**
Interior of drinking water storage container is clean	0.882	0.910	0.901	0.858	**0.471**
	(0.015)	(0.026)	(0.027)	(0.022)	**(0.633)**
Stored drinking water container is located on a platform	0.391	0.382	0.443	0.369	**0.262**
	(0.022)	(0.044)	(0.045)	(0.031)	**(0.773)**
Object used to fetch drinking water from storage container is clean	0.829	0.787	0.860	0.834	**0.307**
	(0.017)	(0.037)	(0.032)	(0.024)	**(0.740)**
Water for general purposes is stored in covered containers	0.699	0.736	0.717	0.672	**0.267**
	(0.020)	(0.040)	(0.040)	(0.030)	**(0.769)**
F-test (p-value) from regression of each treatment assignment on all above covariates		**0.727**	**0.854**	**0.809**	
		(0.679)	**(0.582)**	**(0.616)**	
Observations (N)	**505**	**125**	**127**	**253**	

Notes. *** p<0.01, ** p<0.05, and * p<0.1. Standard errors are presented in parenthesis. The standard errors are adjusted by clustering at the public basic school level. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable of interest. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 40 tests in total for water storage behaviors.

3.3 Water Quality Testing and Information Experiment Impacts on Safe Water Behaviors

This section discusses the demand (take-up), estimation strategy (including basic estimation equations), and the impacts of the household water quality testing and information experiment.

3.3.1 The Demand for Household Water Quality Testing and Information: Take-up of the Experiment

Using an administrative data compiled during the training workshop in July 2014, we analyze take-up of the water quality testing and information experiment. Table 3.3 presents descriptive statistics on the take-up of the water quality testing and information offered by the treatment groups and by gender of participants. If the dissemination of information to the treatment groups concerning the experiment was perfect, then we should expect full compliance (100 percent attendance) in the training workshops. Here attendance in the training workshops is mandatory or a prerequisite for the households to get the water testing kits and handouts on the water quality improvement messages. Recall that the training workshops were held for two days for each participating group (refer to experimental design section for more information on training schedules/approaches). At the end of the training workshop in July 2014, about 99 (79.2 percent) of the 125 school children on the average attended the training workshops. In contrast, about 64 out of 127 adult household members (50.4 percent) on the average participated in the training workshop. Based on the gender of participants, we find that on average more females (about 86 persons) attended the training workshop compared to that of male participants of about 77 persons. We also find that attendance in the training sessions was high for day one compared to day two. Also, male participants were more likely to miss the second day of the training session than their female counterparts. In day one of the training workshop 94 males participated, which reduced to 59 males for day two (a reduction rate of about 37.2 percent). In the case of female participants, during day one training session 92 persons attended and this reduced to 79 (a reduction rate of about 14.1 percent).

Comparing the results generated from the summary statistics to that obtained through first stage analysis was slightly different. Because the first stage analysis defines participation by an individual as one if even the participant attended only one day of the training session (i.e. either day one or day two) but under this section, we apply simple arithmetic of adding-up the number of participants for each day during the training workshop. Of course, there are weaknesses in each approach such as having non-uniform attendance (i.e. a person not attending both days one and two of the training sessions) which further complicates the analysis. Among households/participants in the treatment arms who did not attend the training workshops, the most commonly given explanations include busy with school/business activities, long distance between venue of training and dwelling, late invitation, among others. For brevity, we do not econometrically estimate the factors affecting the demand for household water quality testing and information.

Table 3.3: Details on Take-up of Water Quality Testing and Information Experiment

Day	Total school children	Total adult household members	Total males	Total females
1	107	79	94	92
2	90	48	59	79
Total **	**197**	**127**	**153**	**171**
Average attendance for the two days of training	98.5	63.5	76.5	85.5
Total expected participants	**125**	**127**	---	---

**Double counting

3.3.2 Empirical Strategy: First Stage, Two Stage Least Squares (2SLS) and Reduced Form

We estimate the impacts of household water quality testing and information on a host of safe water behaviors. The outcome variables were selected based on previous studies (Günther and Schipper (2013); Madajewicz *et al*., 2007; Hamoudi *et al*., 2012; Jalan and Somanthan, 2008; Devoto *et al*., (2012); Kremer *et al.* 2011; Lucas *et al.*, (2011); Brown *et al*., 2014) and were pre-specified in an earlier unpublished article and workshop presentations before commencement of the follow-up surveys. For ease of reference, the selected outcomes on safe water behaviors have been classified into five categories: water source choices; water quality, treatment and health risk; water transport, collection, and handling techniques; water quantity, and consumption/usage; and water storage behaviors. In the case of each outcome for the five categories of safe water behaviors, we estimate four parameters of interest. First, the estimation of interest is the effect of households being assigned to a treatment arm(s) and each outcome is examined with specification as:

(2) $Y_{it} = \propto_1 + \beta_1 Treatment_{it} + X'_{it}\gamma_1 + \varepsilon_{it1}$,

where Y_{it} is the outcome variable of interest (for example improved drinking water) for household *i* at time $t(t \in \{1,2,3\}$ for the three follow-up survey rounds), $Treatment_{it}$ is a discrete variable equal 1 if household was assigned to household water quality testing and information, and X'_{it} is a vector of baseline household and community characteristics. Random assignment of households ($Treatment_{it}$) into either project or non-project ensures that $E(\varepsilon_{it1} \mid X_{it}, Treatment_{it}) = 0$, and therefore application of OLS will produce unbiased estimates of coefficients (β_1). Robust standard errors are reported. The reduced form parameter derived from Equation (2) estimates the causality of being assigned to household water quality testing and information. This answer an essential policy question of: what is the impact of offering interested households the option (voluntary participation) of water quality self-testing and information?

Second, we evaluate the average treatment effect of household's actual participation in water quality testing and information on each safe water behaviors. This is based on the premise that if even the water quality self-testing is provided free of charge, not all households will be available for the exercise. Furthermore, actual participation may be hindered by the inability to fully comply with procedures involving water quality testing and recording of the results. This is achieved with estimation analogous to this specification:

(3) $Y_{it} = \propto_2 + \beta_2 Participated_{it} + X'_{it}\gamma_2 + \varepsilon_{it2}$,

where $Participated_{it}$ is a dummy variable which is equal to 1 if the household had a participant in water quality testing and information experiment at time t ($t \in \{1,2,3\}$ for the three follow-up surveys), and is used as instrumental variable with $Treatment_{it}$ as follows:

(4) $Participated_{it} = a + bTreatment_{it} + V_{it}$,

We estimate Equation (3) by the two stage least squares (2SLS) with the first stage equation being Equation (4). The model is just identified, with the 2SLS estimate of β_2 represented by the ratio of the reduced form estimate and that of first stage coefficients (β_1/b). The estimate from the 2SLS is considered as the local average treatment effect (LATE) (Imbens and Angrist, 1994; Angrist *et al*., 1996 and Finkelstein *et al*., 2012). Alternatively, the 2SLS estimate of β_2 identifies causality of participation among the sub-groups of households who would participate in household water quality testing and information on being assigned to the experiment and would not participate in household water quality testing and information without being selected into the experiment. Baseline household and basic school characteristics are included as controls in some specifications (results with columns with even numbers) as sensitivity or robustness checks. The first and second columns of Table 3.4A present the estimation of the first stage equation. In the remaining tables, the estimation of Equation (2) is presented in Panel A while estimation of Equation (3) is shown in Panel B.

Third, we estimate reduced-form model (ITT estimation) for assignment into the treatment arms (school children versus adult household members) and actual participation (IV or LATE estimation) by the two treatment arms on each safe water behaviors. This is based on the premise that the treatment arms may have differential impacts on safe water behaviors. For instance, water source choices may differ across the treatment arms. The estimates of the differential impacts as a function of treatment arms are achieved with regression analogs:

(5) $Y_{it} = \propto_3 + \beta_3 Child\ Treatment_{it} + \beta_4 Adult\ Treatment_{it} + X'_{it}\gamma_3 + \varepsilon_{it3}$,

where $Child\ Treatment_{it}$ is a dummy variable that household *i* was assigned to the school children intervention group in time t and $Adult\ Treatment_{it}$ is a dummy variable that household *i* was assigned to the adult household members intervention group in time t. X'_{it} is the vector of baseline household and basic school controls included in some of the specifications for robustness checks. Actual participation in the household water quality testing and information differs from the treatment assignment and by the two treatment arms (refer to take-up of the experiment section the for more information). This means participation by the treatment arms in the household water quality testing and information is endogenous to the treatment assignment. We quantify the effect of actual participation by the treatment arms in an IV (or LATE) estimation using random allocation of households into the treatment arms as instruments. The estimates for the first stage equation are shown in columns (1) and (2) of Table 3.4B. In the tables under the differential impacts, we present the ITT estimator using OLS in panel A, and estimates of the IV specification using 2SLS in panel B. For complete analysis, we present results with and without baseline household and basic school covariates as controls, columns with even and odd numbers respectively.

Fourth, we are interested in analyzing the average treatment effects of the gender (male versus female) of those that participated in the household water quality testing and information experiment on each safe water behaviors. The estimation is done with specification analogs to this:

(6) $Y_{it} = \propto_4 + \beta_5 Male\_Participated_{it} + X'_{it}\gamma_4 + \varepsilon_{it4}$,

where $Male\_Participated_{it}$ is a dummy variable equal to 1 if the participant is a male, 0 female at time t. To avoid bulking the results of the gendered treatment effects together with impacts and differential impacts under one subsection, the gendered treatment effects for all indicators on safe water behaviors are presented under a common theme as sub-section 3.3.8.

3.3.3.A Impacts on Water Source Choices

The results on the impacts of household water quality testing and information on water source choices are presented in Table 3.4A. For each outcome of interest, we estimate two regressions; (1) without baseline household and basic school covariates (columns with odd numbers) and (2) with baseline household and basic school covariates (columns with even numbers). The results presented include the intention-to-treat (ITT) estimation (Panel A) and instrumental variable (IV) estimation (Panel B) of the impact of the treatment on water source choices. The ITT estimation presents the comparison in changes of water source choices between the treatment and comparison groups regardless of whether households had participants in the water quality testing and/or received the handouts containing water quality improvement messages (information). The ITT estimation avoids the potential of self-selection bias emanating from participation in the water quality testing and information experiment. The IV estimates take into consideration actual participation in the water quality testing and information. Panel A (ITT estimation) of the Tables for this section are estimated with econometric specification analogous to Equation (2) while estimates in Panel B are analyzed using the analogous specification of Equation (3). In the IV estimation, the treatment variable is participation by any of the treatment groups (i.e. either school children intervention group or adult household members intervention group). The first stage shows a high correlation between the treatment assignment indicator and the actual participation (columns 1 and 2). The treatment allocation to water quality testing and information experiment leads to actual participation or uptake of 71.2 percentage points (Panel A, column 1). The result is robust to specifications including baseline household and basic school covariates (Panel A, column 2).

Based on ITT estimation (Panel A), we find less use of surface water as the main source of drinking water (based on WHO's JMP "drinking water ladder" classification). The result shows that use of surface water as the main source of drinking water decreased by 3.4 percentage points (significant at 90 percent, without baseline household and basic school controls). The result is similar for regressions including baseline controls (Panel A, column 10). Furthermore, the use of multiple drinking water sources decreased by 6.7 percentage points (Panel A, column 11). The result is robust to regression specifications including baseline covariates (Panel A, column 12). Household use of multiple water sources for general purposes decreased by 6.9 percentage points (significant at 95 percent, with baseline covariates but not statistically significant without baseline covariates; Panel A, column 14). We find that households offered the water quality testing and information used on average 6.6 percentage points more of improved secondary drinking water sources (using WHO's joint monitoring program (JMP) classification; Panel A, column 15). The result is robust when baseline household and basic school controls are included in the regression (Panel A, column 16).

We find no statistically significant additional effect of household water quality testing and information on other water source choice indicators such as use of improved drinking and general purpose water sources, use of other improved and unimproved main drinking water sources (based on WHO's JMP "drinking water ladder" classification), and finally on the use of sachet water as the main drinking water source. The IV estimation (Panel B) confirms the results obtained using the ITT estimation (Panel A). The signs and statistical significance for the coefficients are the same for all the outcome variables except slight changes in the magnitude of the coefficients. Using the IV estimation makes the estimates slightly higher compared to the ITT estimation.

Table 3.4A: Impacts on Water Source Choices

Dependent variable:	First stage		Water source choices			
	Participated		Improved main drinking water based on JMP		Other improved drinking water source based on JMP	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. ITT Estimation						
Treatment	0.712***	0.747***	0.035	0.028	0.013	-0.007
	(0.017)	(0.016)	(0.024)	(0.024)	(0.025)	(0.026)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1397	1364	1,397	1,364	1,397	1,364
R-squared	0.556	0.597	0.001	0.091	0.000	0.064
Mean (SD) of dependent variable in the comparison group	0	0	0.691	0.691	0.672	0.672
	(0)	(0)	(0.463)	(0.463)	(0.470)	(0.470)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"						
Participated			0.049	0.037	0.018	-0.009
			(0.034)	(0.033)	(0.035)	(0.034)
Household Controls			No	Yes	No	Yes
Basic School Controls			No	Yes	No	Yes
Observations			1,397	1,364	1,397	1,364
R-squared			0.000	0.088	-0.001	0.065
Mean (SD) dependent variable in the comparison group			0.691	0.691	0.672	0.672
			(0.463)	(0.463)	(0.470)	(0.470)

Table 3.4A: Impacts on Water Source Choices (continued)

	Water source choices							
Dependent variable:	Unimproved main drinking water sources based on JMP		Surface water as main drinking water source		Household reports of multiple drinking water sources		Household reports of multiple general purpose water sources	
	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Panel A. ITT Estimation								
Treatment	-0.001	0.007	-0.034*	-0.034*	-0.067***	-0.087***	-0.037	-0.069**
	(0.018)	(0.018)	(0.020)	(0.019)	(0.025)	(0.026)	(0.027)	(0.027)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,397	1,364	1,397	1,364	1,401	1,368	1,401	1,368
R-squared	0.000	0.170	0.002	0.111	0.005	0.033	0.001	0.039
Mean (SD) of dependent variable in the comparison group	0.125 (0.331)	0.125 (0.331)	0.184 (0.388)	0.184 (0.388)	0.685 (0.465)	0.685 (0.465)	0.543 (0.498)	0.543 (0.498)
Panel B. Instrumental variable estimation: “participated” instrumented with “treatment”								
Participated	-0.001	0.009	-0.048*	-0.046*	-0.094***	-0.117***	-0.052	-0.092**
	(0.025)	(0.023)	(0.028)	(0.026)	(0.036)	(0.035)	(0.037)	(0.037)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,397	1,364	1,397	1,364	1,401	1,368	1,401	1,368
R-squared	-0.000	0.171	0.005	0.111	0.006	0.030	-0.000	0.035
Mean (SD) dependent variable in the comparison group	0.125 (0.331)	0.125 (0.331)	0.184 (0.388)	0.184 (0.388)	0.685 (0.465)	0.685 (0.465)	0.543 (0.498)	0.543 (0.498)

Table 3.4A: Impacts on Water Source Choices (continued)

Dependent variable:	Water source choices					
	Improved secondary drinking water source		Improved main general purpose water		Household use sachet water as the main drinking water	
	(15)	(16)	(17)	(18)	(19)	(20)
Panel A. ITT Estimation						
Treatment	0.066**	0.066**	0.036	0.040	0.016	0.027
	(0.030)	(0.031)	(0.027)	(0.027)	(0.019)	(0.019)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	915	892	1,401	1,368	1,397	1,364
R-squared	0.005	0.083	0.001	0.087	0.000	0.184
Mean (SD) of dependent variable in the comparison group	0.663 (0.473)	0.663 (0.473)	0.532 (0.499)	0.532 (0.499)	0.149 (0.356)	0.149 (0.356)
Panel B. Instrumental variable estimation: “participated” instrumented with “treatment”						
Participated	0.095**	0.091**	0.051	0.054	0.022	0.036
	(0.044)	(0.043)	(0.037)	(0.035)	(0.027)	(0.026)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	915	892	1,401	1,368	1,397	1,364
R-squared	-0.004	0.070	0.001	0.083	0.003	0.187
Mean (SD) of dependent variable in the comparison group	0.663 (0.473)	0.663 (0.473)	0.532 (0.499)	0.532 (0.499)	0.149 (0.356)	0.149 (0.356)

Notes: Robust standard errors in parentheses. Baseline household and household head controls include: household head is a male, head’s age, head is married, head belongs to Ga/Adangbe ethnic group, head is a Christian, household is located in urban district (Ga South Municipal), household expenditure is high (i.e. 1 if percentile 50-100 of household annual expenditure), household undertakes irrigated agriculture, household has electricity, and number of female members under 15 years of age. Basic school controls include: school project contact person (i.e. SHEP coordinator) is a male.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Source: First, second and third follow-up survey rounds in November/December 2014, January/February 2015, and May/June 2015.

3.3.3.B Differential Impacts on Water Source Choices

Table 3.4B presents differential treatment effects by the treatment arms (i.e. school children intervention group and adult household members intervention group) using three rounds of follow-up surveys in 2014 and 2015. The results are obtained using regression analogs to Equation (5) to analyze the differential impacts of water quality testing and information on water source choices. In the IV estimation, we instrument by using random assignment into the various treatment arms without any interactions. The first stage estimation is strong. The treatment allocation of households into water quality testing and information experiment increases school children's participation or take-up by 85.2 percentage points (s.e. 1.2 percentage points) while participation or take-up increases by 57.2 percentage points (s.e. 1.9 percentage points) for adult household members.

We find evidence of differential treatment effects based on the various treatment groups. As it was done under the previous section, we estimate two regressions for each outcome variable: (1) without baseline household and basic school controls (columns with odd numbers) and (2) with baseline household and basic school controls (columns with even numbers). Panel A (Column (3)) presents the impacts on the choice of improved drinking water based on WHO's JMP classification. Choice of improved main drinking water sources is 8.4 percentage points higher for households in the school children intervention group (relative to the average value of the comparison group of 69.1 percent), but this is not robust to the inclusion of the baseline covariates. There is no statistically significant additional effect for households in the adult household members intervention group. Furthermore, choice of unimproved drinking water sources increases by 4.6 percentage points for households in the school children intervention group while there is a reduction of 4.4 percentage points in the adult household members intervention group (Panel A, column 8). The results are significant only in specifications with baseline covariates. Panel A, column 9 examines the use of surface water (which comprised of river, streams, canals, etc.) as the main drinking water source. The choice of surface water as the main drinking water source is 9.1 percentage points lower for households in the school children group (relative to average value of 18.4 percent in the comparison group). The result is robust when baseline household and basic school controls are included in the regression (Panel A, column 10). There is no statistically significant reduction for households in the adult household members intervention group.

Panel A, column 11 reports the impact on the use of multiple drinking water sources. Choice of multiple drinking water sources is 8.6 percentage points lower for households in the school children intervention group (relative to average value of 68.5 percent in the comparison group). The result is robust to specifications including baseline household and basic school controls (Panel A, column 12). Households in the adult household members intervention group decrease the use of multiple drinking water sources by 11.1 percentage points (significant at 99 percent, with regression specifications including baseline controls but not significant without baseline controls).

Panel A, column 13 presents the choice of multiple general purpose water sources by households. The choice of multiple general purpose water sources is 10.8 percentage points lower (significant only in regressions with baseline covariates) for households in the adult household members intervention group (relative to average value of 54.3 percent in the comparison group). There is no statistically significant additional effect for households in the school children intervention group. Panel A, column 15 reports the choice of improved secondary drinking water sources based on WHO's JMP classification. Choice of other improved secondary drinking water sources is 14.4 percentage points higher (significant at 99 percent) for the households in adult household members treatment group (relative to average value of 66.3 percent in the comparison group). The result is robust to regression specifications including baseline covariates (Panel A, column 16). There is no statistically significant additional effect for households in the school children intervention group. Panel A, column 17 presents the impacts on choice of improved general purpose water sources. The choice of improved general purpose water sources is 12.6 percentage points higher for the households in the school children intervention group (relative to average value of 53.2 percent in the comparison group). The result is robust to regression specifications including baseline covariates (Panel A, column 18). There is no statistically significant additional effect for households in the adult household members intervention group.

We find an interesting result in relation to shift toward the choice of sachet water as the main drinking water source. The experiment included training of households on water quality testing and how to improve household water quality. From the training sessions, we tested different types of water supply (usually about four types of water sources). In almost all of the cases, sachet/bottled water was the safest in terms of number of *E. coli* per 100 mL. Sachet water is also the most expensive water source aside bottled water with one costing roughly GHS 0.20 (equivalent 5 cents) during the time of the intervention in July 2014, and also depending on the brand. Sachet water has a size of roughly half of a liter (500mL). For household main drinking water sources, we observe significant changes in making cash-intensive choices. Specifically, Panel A, column 19 indicates 14.9 percent of households in the comparison group use sachet water as the main drinking water source. This proportion is increased by 4.7 percentage points among households in the school children intervention group. The result is robust to regression including baseline household and basic school controls (Panel A, column 20). There is no statistically significant additional effect for households in the adult household members intervention group.

The results obtained using the IV estimation (Panel B) for the water source choices are similar to that of the ITT estimation (Panel A). We find slight improvement in the estimates using the IV estimation rather than the ITT estimation. This is highly expected since actual participation will lead to assimilation of the experiment. The level of statistical significance and signs of the estimates are similar to that of the ITT estimation. Lastly, we do not find statistically significant impacts on other water source choice outcome such as use of other improved drinking water sources based on WHO's JMP classification on "drinking water ladder".

Table 3.4B: Differential Impacts on Water Source Choices

	First stage		Water source choices			
Dependent variable:	Child Participated	Adult participated	Improved main drinking water based on JMP		Other improved drinking water source based on JMP	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. ITT Estimation						
Child treatment	0.852***	0.008	0.084***	0.026	0.035	-0.029
	(0.012)	(0.017)	(0.029)	(0.028)	(0.030)	(0.031)
Adult treatment	0.030**	0.572***	-0.014	0.030	-0.009	0.023
	(0.013)	(0.019)	(0.030)	(0.036)	(0.031)	(0.037)
Household Controls	Yes	Yes	No	Yes	No	Yes
Basic School Controls	Yes	Yes	No	Yes	No	Yes
Observations	1364	1364	1,397	1,364	1,397	1,364
R-squared	0.831	0.516	0.007	0.091	0.001	0.065
Mean (SD) of dependent variable in the comparison group	0 (0)	0 (0)	0.691 (0.463)	0.691 (0.463)	0.672 (0.470)	0.672 (0.470)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"						
Child participated			0.098***	0.030	0.041	-0.035
			(0.034)	(0.032)	(0.036)	(0.036)
Adult participated			-0.024	0.050	-0.017	0.041
			(0.053)	(0.063)	(0.054)	(0.064)
Household Controls			No	Yes	No	Yes
Basic School Controls			No	Yes	No	Yes
Observations			1,397	1,364	1,397	1,364
R-squared			0.004	0.088	-0.001	0.065
Mean (SD) dependent variable in the comparison group			0.691 (0.463)	0.691 (0.463)	0.672 (0.470)	0.672 (0.470)

Table 3.4B: Differential Impacts on Water Source Choices (continued)

Dependent variable:	Water source choices							
	Unimproved main drinking water sources based on JMP		Surface water as main drinking water source		Household reports of multiple drinking water sources		Household reports of multiple general purpose water sources	
	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Panel A. ITT Estimation								
Child treatment	0.007	0.046**	-0.091***	-0.072***	-0.086***	-0.070**	-0.023	-0.038
	(0.022)	(0.019)	(0.022)	(0.022)	(0.032)	(0.034)	(0.033)	(0.034)
Adult treatment	-0.008	-0.044*	0.021	0.014	-0.048	-0.111***	-0.052	-0.108***
	(0.021)	(0.025)	(0.026)	(0.030)	(0.031)	(0.037)	(0.033)	(0.039)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,397	1,364	1,397	1,364	1,401	1,368	1,401	1,368
R-squared	0.000	0.175	0.013	0.115	0.006	0.034	0.002	0.041
Mean (SD) of dependent variable in the comparison group	0.125 (0.331)	0.125 (0.331)	0.184 (0.388)	0.184 (0.388)	0.685 (0.465)	0.685 (0.465)	0.543 (0.498)	0.543 (0.498)
Panel B. Instrumental variable estimation: “child participated” and “adult participated” instrumented with “child treatment” and “adult treatment”								
Child participated	0.008	0.055**	-0.106***	-0.085***	-0.101***	-0.080**	-0.026	-0.044
	(0.026)	(0.022)	(0.025)	(0.025)	(0.037)	(0.040)	(0.038)	(0.040)
Adult participated	-0.013	-0.080*	0.037	0.030	-0.084	-0.189***	-0.090	-0.187***
	(0.037)	(0.043)	(0.046)	(0.053)	(0.054)	(0.064)	(0.057)	(0.068)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,397	1,364	1,397	1,364	1,401	1,368	1,401	1,368
R-squared	-0.000	0.169	0.010	0.113	0.006	0.030	-0.001	0.032
Mean (SD) dependent variable in the comparison group	0.125 (0.331)	0.125 (0.331)	0.184 (0.388)	0.184 (0.388)	0.685 (0.465)	0.685 (0.465)	0.543 (0.498)	0.543 (0.498)

Table 3.4B: Differential Impacts on Water Source Choices (continued)

	Water source choices					
Dependent variable:	Improved secondary drinking water source		Improved main general purpose water		Household use sachet water as the main drinking water	
	(15)	(16)	(17)	(18)	(19)	(20)
Panel A. ITT Estimation						
Child treatment	-0.019	-0.013	0.126***	0.075**	0.047*	0.079***
	(0.040)	(0.041)	(0.032)	(0.033)	(0.025)	(0.022)
Adult treatment	0.144***	0.163***	-0.052	-0.004	-0.015	-0.041
	(0.034)	(0.044)	(0.033)	(0.038)	(0.023)	(0.027)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	915	892	1,401	1,368	1,397	1,364
R-squared	0.020	0.093	0.017	0.089	0.004	0.192
Mean (SD) of dependent variable in the comparison group	0.663 (0.473)	0.663 (0.473)	0.532 (0.499)	0.532 (0.499)	0.149 (0.356)	0.149 (0.356)
Panel B. Instrumental variable estimation: “child participated” and “adult participated” instrumented with “child treatment” and “adult treatment”						
Child participated	-0.023	-0.018	0.148***	0.088**	0.055*	0.093***
	(0.047)	(0.048)	(0.037)	(0.039)	(0.029)	(0.025)
Adult participated	0.261***	0.305***	-0.090	-0.012	-0.026	-0.076
	(0.064)	(0.085)	(0.057)	(0.066)	(0.039)	(0.047)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	915	892	1,401	1,368	1,397	1,364
R-squared	-0.003	0.054	0.012	0.086	0.008	0.193
Mean (SD) dependent variable in the comparison group	0.663 (0.473)	0.663 (0.473)	0.532 (0.499)	0.532 (0.499)	0.149 (0.356)	0.149 (0.356)

Notes: Robust standard errors in parentheses. Household and household head baseline controls include: household head is a male, head’s age, head is married, head belongs to Ga/Adangbe ethnic group, head is a Christian, household is located in urban district (Ga South Municipal), household expenditure is high (i.e. 1 if percentile 50-100 of household annual expenditure), household undertakes irrigated agriculture, household has electricity, and number of female members under 15 years of age. Basic school controls include: school project contact person (i.e. SHEP coordinator) is a male.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Source: First, second and third follow-up survey rounds in November/December 2014, January/February 2015, and May/June 2015.

3.3.4.A Impacts on Water Quality, Treatment and Health Risk

Using a regression with specification analogs to Equations (2) and (3) we estimate the impacts of household water quality and information on perception of the households on water quality, water treatment and health risk (Table 3.5A). We include in some of the specifications baseline household and basic school characteristics as controls and also estimate separate regressions for differential treatment effects as a function of random allocation into the two treatment arms, and finally report robust standard errors. Recall that the experiment involved information component and practical aspects (including the training exercise) which allow us to analyze the perceptions of the households on water quality, treatment, and health risk. We find that households in the treatment group are 7.3 percentage points less likely to report of being satisfied with water quality (Panel A, column 5; relative to the average value of comparison group of 77 percent). The result is robust to regressions including baseline household and basic school controls. In Panel A, column 8, household self-report of water treatment is lower by 3.7 percentage points in the intervention group (significant at 90 percent, with baseline covariates but not significant without baseline covariates). Other than these, we do not find statistically significant additional effect of household water quality testing and information on other perceptions on water quality, treatment and health risk variables such as main drinking water source being dirty, among others.

Table 3.5A: Impacts on Water Quality, Treatment and Health Risk

	Water Quality, Treatment and Health Risk							
Dependent variable:	Main drinking water source is dirty		Main general purpose water source is dirty		Satisfied with water quality		Household treat water to make it safer to drink	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. ITT Estimation								
Treatment	0.013	-0.000	-0.004	-0.026	-0.073***	-0.052**	-0.022	-0.037*
	(0.018)	(0.019)	(0.022)	(0.022)	(0.024)	(0.024)	(0.021)	(0.021)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,383	1,351	1,390	1,357	1,400	1,367	1,373	1,340
R-squared	0.000	0.043	0.000	0.057	0.007	0.058	0.001	0.042
Mean (SD) of dependent variable in the comparison group	0.130 (0.336)	0.130 (0.336)	0.223 (0.416)	0.223 (0.416)	0.770 (0.421)	0.770 (0.421)	0.192 (0.394)	0.192 (0.394)
Panel B. Instrumental variable estimation: “participated” instrumented with “treatment”								
Participated	0.018	-0.000	-0.005	-0.035	-0.103***	-0.070**	-0.031	-0.050*
	(0.026)	(0.025)	(0.031)	(0.030)	(0.033)	(0.032)	(0.029)	(0.028)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,383	1,351	1,390	1,357	1,400	1,367	1,373	1,340
R-squared	-0.002	0.043	0.001	0.058	-0.012	0.051	0.003	0.041
Mean (SD) dependent variable in the comparison group	0.130 (0.336)	0.130 (0.336)	0.223 (0.416)	0.223 (0.416)	0.770 (0.421)	0.770 (0.421)	0.192 (0.394)	0.192 (0.394)

Notes: Refer to Table 3.4A

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

3.3.4.B Differential Impacts on Water Quality, Treatment and Health Risk

Table 3.5B estimates the differential impacts of the household water quality testing and information on the household perceptions on water quality, treatment, and health risk. In general, we find that participation in the household water quality testing and information leads to substantial differential impacts for the two treatment groups.

In Panel A, column 1, households in the school children intervention group are on average 3.4 percentage points (significant at 90 percent, without baseline household and basic school controls but not significant with baseline household and basic school controls) less likely of reporting that the main drinking water source is dirty (relative to average value of 13 percent of the comparison group). Similarly, households in the adult household members intervention group are on average 5.8 percentage more likely of reporting dirty water from main drinking water source (significant at 95 percent, without baseline household and basic school controls but not significant with baseline household and basic school controls).

The results in Panel A, column 3 shows that households in the school children intervention group are 9.3 percentage points less likely of reporting that their main general purpose water source is dirty (relative to the average value of 22.3 percent in the comparison group). Households in the adult household members intervention group are 8.4 percentage points more likely of reporting that the main general purpose water source is dirty compared to the comparison group. The results are robust to regressions including baseline household and basic school controls (Panel A, column 4).

Based on Panel A, column 5, satisfaction with water quality in households in the adult household members intervention group are 18.4 percentage points lower (relative to the average value of 77 percent in the comparison group). There is no statistically significant additional effect for households in the school children intervention group. Panel A, column 7 presents impacts on household water treatment. Water treatment is 8.2 percentage points lower in households in school children intervention group compared to the control group. The average value for the comparison group is 19.2 percent. The result is robust to regressions including household and basic school baseline controls (Panel A, column 8). We do not find a statistically significant additional effect for households in the adult household members intervention group.

Table 3.5B: Differential Impacts on Water Quality, Treatment and Health Risk

	Water Quality, Treatment and Health Risk							
Dependent variable:	Main drinking water source is dirty		Main general purpose water source is dirty		Satisfied with water quality		Household treat water to make it safer to drink	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. ITT Estimation								
Child treatment	-0.034*	-0.031	-0.093***	-0.096***	0.040	0.036	-0.082***	-0.073***
	(0.021)	(0.021)	(0.024)	(0.025)	(0.026)	(0.028)	(0.023)	(0.023)
Adult treatment	0.058**	0.039	0.084***	0.071**	-0.184***	-0.180***	0.036	0.024
	(0.025)		(0.029)	(0.030)	(0.031)	(0.032)	(0.027)	(0.028)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,383	1,351	1,390	1,357	1,400	1,367	1,373	1,340
R-squared	0.009	0.046	0.022	0.064	0.039	0.064	0.012	0.038
Mean (SD) of dependent variable in the comparison group	0.130	0.130	0.223	0.223	0.770	0.770	0.192	0.192
	(0.336)	(0.336)	(0.416)	(0.416)	(0.421)	(0.421)	(0.394)	(0.394)
Panel B. Instrumental variable estimation: “child participated” and “adult participated” instrumented with “child treatment” and “adult treatment”								
Child participated	-0.040*	-0.038	-0.109***	-0.102***	0.047	0.023	-0.096***	-0.063**
	(0.024)	(0.025)	(0.028)	(0.031)	(0.031)	(0.033)	(0.027)	(0.028)
Adult participated	0.100**	0.073	0.146***	0.095	-0.321***	-0.250***	0.063	-0.023
								(0.057)
	(0.043)	(0.050)	(0.052)	(0.061)	(0.057)	(0.065)	(0.048)	
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,383	1,351	1,390	1,357	1,400	1,367	1,373	1,340
R-squared	-0.003	0.038	0.007	0.057	-0.019	0.033	0.005	0.041
Mean (SD) dependent variable in the comparison group	0.130	0.130	0.223	0.223	0.770	0.770	0.192	0.192
	(0.336)	(0.336)	(0.416)	(0.416)	(0.421)	(0.421)	(0.394)	(0.394)

Notes: Refer to Table 3.4B

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

3.3.5.A Impacts on Water Transport, Collection and Handling Techniques

Next, in Table 3.6A, we explore the impacts of the household water quality testing and information experiment on water transport, collection and handling techniques. Recall that from the previous sub-section 3.3.3.A there were gains in water source choices, particularly in terms of improved secondary drinking water sources, among others. Therefore, we examine whether these gains in the choice of water sources translate to households making time gains or otherwise investing more time looking for safer water sources. We find evidence of households in the treatment group making substantial time gains in terms of minutes and distance saved from water collection trips.

Panel A, column 1, reports the impact on the one-way distance to main drinking water source (in meters). Distance to main drinking water source is on average 32.46 meters less for households in the treatment group (relative to the average value of 188.92 meters of the comparison group). The result is robust to regressions including baseline household and basic school characteristics (Panel A, column 2). Likewise, Panel A, column 3 shows that households in the treatment group travel on average 38.1 meters less in fetching main general purpose water (relative to the average value of 208.82 meters of the comparison group). The result is robust to regression specifications including household and basic school characteristics. In terms of time savings, households in the treatment group travel on average 1.40 minutes less (significant at 95 percent, with regressions including baseline controls) to and from main drinking water source (relative to the average value of 11.31 minutes of the comparison group). Similarly, there is a reduction in time spent traveling to and from main general purpose water source of about 1.51 minutes for households in the treatment group (Panel A, column 7). The result is robust to regression specifications including baseline covariates. The time and distance gains are substantial since households in the comparison group have on average 42.58 water fetching trips per week preceding the surveys.

Panel A, Columns (9) and (10) examine the households' use of children as labor for water fetching. Column 10 shows that households in the treatment group are on the average 5.6 percentage points less (significant at 95 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls) likely to use children less than 12 years of age in water collection (relative to average value of 40 percent in the comparison group). The IV estimation (Panel B) confirms the results obtained using the ITT estimation (Panel A). The signs and statistical significance are the same for all the outcome variables. Using the IV estimation makes the estimates slightly higher compared to the ITT estimation.

Table 3.6A: Impacts on Water Transport, Collection and Handling Techniques

	Water Transport, Collection and Handling Techniques					
Dependent variable:	Distance to main drinking water (in meters)		Distance to main general purpose water (in meters)		Time to main drinking water source (in minutes)	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. ITT Estimation						
Treatment	-32.459***	-46.035***	-38.052***	-50.502***	-1.018	-1.404**
	(11.922)	(12.115)	(11.446)	(11.600)	(0.669)	(0.618)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,294	1,263	1,343	1,310	1,339	1,307
R-squared	0.006	0.060	0.008	0.075	0.002	0.057
Mean (SD) of dependent variable in the comparison group	188.920 (238.309)	188.920 (238.309)	208.815 (235.758)	208.815 (235.758)	11.311 (12.443)	11.311 (12.443)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"						
Participated	-45.734***	-61.828***	-53.273***	-67.412***	-1.439	-1.888**
	(16.726)	(16.178)	(15.919)	(15.370)	(0.943)	(0.826)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,294	1,263	1,343	1,310	1,339	1,307
R-squared	0.012	0.058	0.019	0.075	0.006	0.058
Mean (SD) dependent variable in the comparison group	188.920 (238.309)	188.920 (238.309)	208.815 (235.758)	208.815 (235.758)	11.311 (12.443)	11.311 (12.443)

Table 3.6A: Impacts on Water Transport, Collection and Handling Techniques (continued)

	Water Transport, Collection and Handling Techniques			
Dependent variable:	Time to main general purpose water source (in minutes)		Children under 12 years fetch water	
	(7)	(8)	(9)	(10)
Panel A. ITT Estimation				
Treatment	-1.511**	-2.334***	-0.037	-0.056**
	(0.697)	(0.670)	(0.026)	(0.026)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,348	1,316	1,359	1,326
R-squared	0.003	0.055	0.001	0.113
Mean (SD) of dependent variable in the comparison group	13.263	13.263	0.400	0.400
	(12.411)	(12.411)	(0.490)	(0.490)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"				
Participated	-2.124**	-3.122***	-0.052	-0.075**
	(0.975)	(0.889)	(0.037)	(0.035)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,348	1,316	1,359	1,326
R-squared	0.010	0.054	0.003	0.114
Mean (SD) dependent variable in the comparison group	13.263	13.263	0.400	0.400
	(12.411)	(12.411)	(0.490)	(0.490)

Notes: Refer to Table 3.4A

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

3.3.5.B Differential Impacts on Water Transport, Collection and Handling Techniques

In Table 3.6B, we examine the differential treatment effects as a function of random allocation into the treatment arms using econometric specification analogous to Equations (5). We find evidence of differential treatment effects for time and distance gains in water collection for households in school children and adult household members intervention groups. Panel A, column 1 reports impacts on the distance to main drinking water source. Distance to main drinking water source is 55.01 meters lower (significant at 99 percent) for households in the school children intervention group (relative to the average value of 188.92 meters of the comparison group). The result is robust to specifications including baseline household and basic school controls (Panel A, column 2). There is a reduction of 38.11 meters in distance to main drinking water source for households in the adult household members intervention group (significant at 95 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls).

Panel A, column 3, presents the impacts on the distance to main general purpose water source. Distance to main general purpose water source is 59.53 meters lower (significant at 99 percent) for households in the school children intervention group (relative to the average value of 208.82 meters of the comparison group). The result is robust to regressions including baseline household covariates. We find a statistically significant reduction of 53.82 meters in distance to main general purpose water source for households in the adult household members intervention group (significant at 99 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls).

We show that reduction in distance leads to a commensurate reduction in the time taken to reach and return from both drinking and general purpose water sources (Panel A, columns (5)-(8)). Specifically, Panel A, column 5 shows that on average the comparison group spends 11.31 minutes traveling to and from main drinking water source. This proportion is decreased by 3.23 minutes among households in the school children intervention group. The result is robust to regressions with the inclusion of baseline household and basic school controls (Panel A, column 6). We do not find a statistically significant reduction in minutes taken to and from main drinking water source for households in the adult household members intervention group. In the case of time taken to and from main general purpose water source, Panel A, column 7 shows that the comparison group spends on average 13.26 minutes. This proportion is reduced by 2.75 minutes for households in the school children intervention group. The result is robust to specifications including baseline household and basic school characteristics (Panel A, column 8). Households in the adult household members intervention group make time savings of 2.49 minutes (significant at 95 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls).

Columns (9) and (10) examine the differential impacts on the use of child labor in the fetching of water among the households. The use of children under 12 years of age for water collection decreased by 6.1 percentage points in households in the school children intervention group (significant at 90 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls). We find no statistically significant reduction in the use of children under 12 years of age in water collection for households in the adult household members intervention group. This means the results in columns 11 and 12 show that households in the school children intervention group rely on children above 12 years in performing water collection tasks. The result is interesting in the sense that on the average households in the school children intervention group rely on "older" children (i.e. those above 12 years of age in fetching water) compared to their counterparts in the comparison group.

Table 3.6B: Differential Impacts on Water Transport, Collection and Handling Techniques

	Water Transport, Collection and Handling Techniques					
Dependent variable:	Distance to main drinking water (in meters)		Distance to main general purpose water (in meters)		Time to main drinking water source (in minutes)	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. ITT Estimation						
Child treatment	-55.064***	-52.098***	-59.533***	-47.901***	-3.234***	-3.208***
	(13.574)	(13.123)	(13.554)	(12.808)	(0.643)	(0.666)
Adult treatment	-10.909	-38.114**	-17.538	-53.816***	1.022	0.875
	(14.484)	(17.938)	(13.321)	(17.089)	(0.928)	(1.026)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,294	1,263	1,343	1,310	1,339	1,307
R-squared	0.011	0.060	0.013	0.075	0.016	0.065
Mean (SD) of dependent variable in the comparison group	188.920	188.920	208.815	208.815	11.311	11.311
	(238.309)	(238.309)	(235.758)	(235.758)	(12.443)	(12.443)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"						
Child participated	-65.819***	-61.449***	-70.378***	-55.973***	-3.849***	-3.823***
	(16.149)	(15.543)	(15.911)	(15.077)	(0.766)	(0.795)
Adult participated	-18.529	-62.546**	-29.797	-88.674***	1.746	1.686
	(24.518)	(30.486)	(22.482)	(28.615)	(1.590)	(1.754)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,294	1,263	1,343	1,310	1,339	1,307
R-squared	0.014	0.058	0.020	0.075	0.012	0.059
Mean (SD) dependent variable in the comparison group	188.920	188.920	208.815	208.815	11.311	11.311
	(238.309)	(238.309)	(235.758)	(235.758)	(12.443)	(12.443)

Notes: Refer to Table 3.4B

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 3.6B: Differential Impacts on Water Transport, Collection and Handling Techniques (continued)

	Water Transport, Collection and Handling Techniques			
Dependent variable:	Time to main general purpose water source (in minutes)		Children under 12 years fetch water	
	(7)	(8)	(9)	(10)
Panel A. ITT Estimation				
Child treatment	-2.749***	-2.209***	-0.027	-0.061*
	(0.791)	(0.810)	(0.033)	(0.032)
Adult treatment	-0.355	-2.492**	-0.046	-0.050
	(0.921)	(1.069)	(0.032)	(0.037)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,348	1,316	1,359	1,326
R-squared	0.008	0.056	0.002	0.113
Mean (SD) of dependent variable in the comparison group	13.263 (12.411)	13.263 (12.411)	0.400 (0.490)	0.400 (0.490)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"				
Child participated	-3.243***	-2.569***	-0.032	-0.071*
	(0.929)	(0.953)	(0.038)	(0.037)
Adult participated	-0.607	-4.153**	-0.080	-0.083
	(1.572)	(1.823)	(0.056)	(0.064)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,348	1,316	1,359	1,326
R-squared	0.011	0.054	0.003	0.114
Mean (SD) dependent variable in the comparison group	13.263 (12.411)	13.263 (12.411)	0.400 (0.490)	0.400 (0.490)

Notes: Refer to Table 3.4B

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

3.3.6.A Impacts on Water Quantity and Consumption/Usage

In Table 3.7A, we present the impacts of household water quality testing and information on water quantity and consumption/usage. We find that there is no statistically significant additional effect on water quantity, and consumption indicators, consistent with water quality testing and information improving knowledge, awareness, and beliefs on water quality but not water quantity. The results from the IV estimation (Panel B) are similar to those achieved with the ITT estimation (Panel A).

Table 3.7A: Impacts on Water Quantity and Consumption/Usage

	Water Quantity and Consumption/Usage			
Dependent variable:	Volume (liters) of drinking water consumed (past 2 days)		Volume (liters) of general purpose water consumed (past 2 days)	
	(1)	(2)	(3)	(4)
Panel A. ITT Estimation				
Treatment	-1.639	-2.020	-5.987	-7.204
	(3.175)	(2.846)	(9.679)	(8.752)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,391	1,358	1,398	1,365
R-squared	0.000	0.040	0.000	0.128
Mean (SD) of dependent variable in the comparison group	50.895 (60.824)	50.895 (60.824)	296.584 (190.170)	296.584 (190.170)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"				
Participated	-2.301	-2.704	-8.409	-9.645
	(4.453)	(3.789)	(13.585)	(11.665)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,391	1,358	1,398	1,365
R-squared	0.001	0.041	0.000	0.127
Mean (SD) dependent variable in the comparison group	50.895 (60.824)	50.895 (60.824)	296.584 (190.170)	296.584 (190.170)

Notes: Refer to Table 3.4A

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

3.3.6.B Differential Impacts on Water Quantity and Consumption/Usage

Table 3.7B shows the differential impacts on water quantity and consumption/usage. We find no evidence of the additional effect of water quality testing and information on household water quantity and consumption/usage. This is consistent with the idea that household water quality testing and information affects water quality related issues and not that of water quantity. The IV estimation (Panel B) generates similar estimates as the ITT estimation (Panel A).

Table 3.7B: Differential Impacts on Water Quantity and Consumption/Usage

Dependent variable:	Water Quantity and Consumption/Usage			
	Volume (liters) of drinking water consumed (past 2 days)		Volume (liters) of general purpose water consumed (past 2 days)	
	(1)	(2)	(3)	(4)
Panel A. ITT Estimation				
Child treatment	0.292	-1.326	5.168	-7.143
	(3.607)	(3.809)	(11.448)	(11.440)
Adult treatment	-3.514	-2.911	-16.856	-7.281
	(4.085)	(4.423)	(11.856)	(13.226)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,391	1,358	1,398	1,365
R-squared	0.001	0.040	0.002	0.128
Mean (SD) of dependent variable in the comparison group	50.895 (60.824)	50.895 (60.824)	296.584 (190.170)	296.584 (190.170)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"				
Child participated	0.342	-1.514	6.056	-8.280
	(4.228)	(4.453)	(13.411)	(13.361)
Adult participated	-6.102	-4.994	-29.351	-12.291
	(7.087)	(7.681)	(20.688)	(23.040)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,391	1,358	1,398	1,365
R-squared	0.000	0.040	-0.001	0.127
Mean (SD) dependent variable in the comparison group	50.895 (60.824)	50.895 (60.824)	296.584 (190.170)	296.584 (190.170)

Notes: Refer to Table 3.4B

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

3.3.7.A Impacts on Water Storage

We estimate the impacts of water quality testing and information on a host of water storage behaviors (Table 3.8A). Empirically, we find statistically significant changes in water storage behaviors. In Panel A, column 1, we find that households in the treatment group on average decrease stocking drinking water in the house (not counting bottled/sachet water) by 4 percentage points compared to the control group. The result is robust to specifications including baseline household and basic school controls (Panel A, column 2). In Panel A, column 9 we find that treated households are 4.2 percentage points more likely of using only plain water for washing drinking water storage containers (significant at 90 percent, without baseline household and basic school controls but not significant with baseline household and basic school controls).

Using field enumerator observations, we find that treated households are 2.7 percentage points more likely to have their drinking water storage containers covered (Panel A, column 11). The result is robust to specifications with baseline household controls (Panel A, column 12). Treated households are on average 3 percentage points (significant at 90 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls) more likely of having the interior of drinking water storage container observed to be clean (Panel A, column 14). Households in the intervention group are 4.7 percent (significant at 90 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls) more likely to store general purpose water in covered containers (Panel A, column 20). We find no statistically significant effects on other storage behavior indicators such as main drinking water storage container is set on the ground, among others.

Table 3.8A: Impacts on Water Storage

	Water Storage			
Dependent variable:	Usually stock drinking water in the house		Container is set on the ground	
	(1)	(2)	(3)	(4)
Panel A. ITT Estimation				
Treatment	-0.040**	-0.053***	0.006	0.009
	(0.016)	(0.017)	(0.028)	(0.028)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,399	1,366	1,244	1,212
R-squared	0.004	0.106	0.000	0.155
Mean (SD) of dependent variable in the comparison group	0.917 (0.277)	0.917 (0.277)	0.582 (0.494)	0.582 (0.494)
Panel B. Instrumental variable estimation: “participated” instrumented with “treatment”				
Participated	-0.056**	-0.071***	0.009	0.012
	(0.023)	(0.023)	(0.041)	(0.038)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,399	1,366	1,244	1,212
R-squared	0.013	0.113	-0.000	0.154
Mean (SD) dependent variable in the comparison group	0.917 (0.277)	0.917 (0.277)	0.582 (0.494)	0.582 (0.494)

Table 3.8A: Impacts on Water Storage (continued)

	Water Storage							
Dependent variable:	Container closed by a lid or cork		Used soap or detergent to wash container the last time		Used only plain water in washing the container the last time		Drinking water storage container is covered	
	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A. ITT Estimation								
Treatment	0.017	0.023	-0.037	-0.025	0.042*	0.030	0.027**	0.033**
	(0.014)	(0.016)	(0.025)	(0.026)	(0.025)	(0.025)	(0.012)	(0.013)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,245	1,213	1,246	1,214	1,246	1,214	1,240	1,208
R-squared	0.001	0.037	0.002	0.088	0.002	0.084	0.004	0.030
Mean (SD) of dependent variable in the comparison group	0.925	0.925	0.741	0.741	0.240	0.240	0.938	0.938
	(0.264)	(0.264)	(0.438)	(0.438)	(0.428)	(0.428)	(0.240)	(0.240)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"								
Participated	0.025	0.032	-0.054	-0.034	0.062*	0.041	0.039**	0.045**
	(0.021)	(0.021)	(0.037)	(0.035)	(0.036)	(0.034)	(0.018)	(0.017)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,245	1,213	1,246	1,214	1,246	1,214	1,240	1,208
R-squared	-0.001	0.034	0.001	0.089	-0.001	0.085	-0.003	0.023
Mean (SD) dependent variable in the comparison group	0.925	0.925	0.741	0.741	0.240	0.240	0.938	0.938
	(0.264)	(0.264)	(0.438)	(0.438)	(0.428)	(0.428)	(0.240)	(0.240)

Table 3.8A: Impacts on Water Storage (continued)

	Water Storage							
Dependent variable:	Interior of drinking water storage container is clean		Stored drinking water container is located on a platform		Object used to fetch drinking water from storage container is clean		Water for general purposes is stored in covered containers	
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Panel A. ITT Estimation								
Treatment	0.019	0.030*	-0.000	-0.007	0.001	0.003	0.033	0.047*
	(0.016)	(0.018)	(0.028)	(0.028)	(0.014)	(0.014)	(0.027)	(0.027)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,241	1,209	1,261	1,229	1,248	1,216	1,353	1,321
R-squared	0.001	0.021	0.000	0.127	0.000	0.018	0.001	0.080
Mean (SD) of dependent variable in the comparison group	0.904 (0.295)	0.904 (0.295)	0.440 (0.497)	0.440 (0.497)	0.931 (0.253)	0.931 (0.253)	0.548 (0.498)	0.548 (0.498)
Panel B. Instrumental variable estimation: “participated” instrumented with “treatment”								
Participated	0.027	0.040*	-0.001	-0.010	0.002	0.004	0.046	0.063*
	(0.023)	(0.024)	(0.041)	(0.038)	(0.021)	(0.019)	(0.038)	(0.036)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,241	1,209	1,261	1,229	1,248	1,216	1,353	1,321
R-squared	0.002	0.020	-0.000	0.126	0.000	0.018	-0.000	0.075
Mean (SD) dependent variable in the comparison group	0.904 (0.295)	0.904 (0.295)	0.440 (0.497)	0.440 (0.497)	0.931 (0.253)	0.931 (0.253)	0.548 (0.498)	0.548 (0.498)

Notes: Refer to Table 3.4A

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

3.3.7.B Differential Impacts on Water Storage

Assignment to water quality testing and information treatment leads to differential impacts on water storage behaviors (Table 3.8B). Respondents in the school children intervention group are 9.5 percentage points less likely of usually stocking drinking water in the house aside bottled/sachet water (relative to the average value of 91.7 percent in the comparison group). The result is robust to specifications with baseline household controls (Panel A, column 2).

There is no statistically significant additional effect for those households in the adult household members intervention group.

Panel A, columns (3) and (4) examines the impacts on household water storage container being set on the ground. We find that households in the adult household members intervention group are 6.9 percentage points more likely to have drinking water storage container set on the ground (relative to the average value of 58.2 percent in the comparison group). Households in the school children intervention group are 6.6 percentage points less likely of having stored drinking water container set on the ground than the control group. The results are robust to regressions including baseline covariates.

Panel A, column 8 shows that households in the school children intervention group are 7.7 percentage points (significant at 95 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls) less likely of using soap/detergent in washing drinking water storage containers (relative to the average value of 74.1 percent in the comparison group). There is no additional effect for households in the adult household members intervention group.

In Panel A, column 9, we find that households in the school children intervention group are 5.9 percentage points more likely of using plain water in washing drinking water storage containers (relative to the average value of 24 percent in the comparison group). The result is robust to regression specifications including baseline controls (Panel A, column 10). We find no statistically significant additional effect for households in the adult household members intervention group.

The results in Panel A, column 11 shows that households in the school children intervention group are 4 percentage points more likely of having drinking water storage container covered based on field enumerator observation (relative to the average value of 93.8 percent in the comparison group). The result obtained is robust to regressions with baseline household and basic school covariates (Panel A, column 12). There is no statistically significant additional effect for households in the adult household members intervention group.

Panel A, column 13 shows that households in the school children intervention group are 4.7 percentage points more likely of having the interior of drinking water storage container being clean (relative to the average value of 90.4 percent in the comparison group). The result is robust to specifications with baseline household controls. We do not find an additional effect for households in the adult household members intervention group. We also find that households in the school children intervention group are 6.7 percentage points (significant at 90 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls) more likely to have stored drinking water container being located on a platform (relative to average value of 44 percent in the comparison group; Panel A, column 16). However, households in the adult household members intervention group are 10.2 percentage points (significant at 99 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls) less likely of placing stored drinking water container on a platform.

In Panel A, column 17 we show that households in the school children intervention group are 3.7 percentage points more likely to use “clean” object in fetching drinking water from a storage container (relative to the average value of 93.1 percent in the comparison group). The result is robust to regressions with baseline household and basic school controls (Panel A, column 18). We do not find an additional effect for households in the adult household members intervention group. Panel A, column 19 shows that households in the school children intervention group are 6.4 percentage points (significant at 90 percent, without baseline household and basic school controls but not significant with baseline household and basic school controls) more likely to have stored water for general purposes in covered containers. There is no statistically significant effect for households in the adult household members intervention group.

Table 3.8B: Differential Impacts on Water Storage

	Water Storage			
Dependent variable:	Usually stock drinking water in the house		Container is set on the ground	
	(1)	(2)	(3)	(4)
Panel A. ITT Estimation				
Child treatment	-0.095***	-0.111***	-0.066*	-0.097***
	(0.023)	(0.021)	(0.036)	(0.034)
Adult treatment	0.015	0.022	0.069**	0.146***
	(0.017)	(0.023)	(0.033)	(0.038)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,399	1,366	1,244	1,212
R-squared	0.020	0.121	0.009	0.174
Mean (SD) of dependent variable in the comparison group	0.917	0.917	0.582	0.582
	(0.277)	(0.277)	(0.494)	(0.494)
Panel B. Instrumental variable estimation: “child participated” and “adult participated” instrumented with “child treatment” and “adult treatment”				
Child participated	-0.111***	-0.130***	-0.080*	-0.120***
	(0.027)	(0.024)	(0.043)	(0.041)
Adult participated	0.025	0.045	0.122**	0.265***
	(0.030)	(0.040)	(0.058)	(0.070)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	1,399	1,366	1,244	1,212
R-squared	0.029	0.124	0.000	0.142
Mean (SD) dependent variable in the comparison group	0.917	0.917	0.582	0.582
	(0.277)	(0.277)	(0.494)	(0.494)

Table 3.8B: Differential Impacts on Water Storage (continued)

	Water Storage							
Dependent variable:	Container closed by a lid or cork		Used soap or detergent to wash container the last time		Used only plain water in washing the container the last time		Drinking water storage container is covered	
	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A. ITT Estimation								
Child treatment	0.022	0.021	-0.047	-0.077**	0.059*	0.080**	0.040***	0.042***
	(0.017)	(0.017)	(0.033)	(0.032)	(0.032)	(0.032)	(0.013)	(0.013)
Adult treatment	0.013	0.027	-0.028	0.043	0.028	-0.034	0.015	0.022
	(0.017)	(0.023)	(0.031)	(0.037)	(0.030)	(0.036)	(0.015)	(0.019)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,245	1,213	1,246	1,214	1,246	1,214	1,240	1,208
R-squared	0.001	0.037	0.002	0.093	0.003	0.090	0.006	0.030
Mean (SD) of dependent variable in the comparison group	0.925 (0.264)	0.925 (0.264)	0.741 (0.438)	0.741 (0.438)	0.240 (0.428)	0.240 (0.428)	0.938 (0.240)	0.938 (0.240)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"								
Child participated	0.026	0.024	-0.057	-0.093**	0.071*	0.097**	0.049***	0.050***
	(0.021)	(0.020)	(0.039)	(0.038)	(0.039)	(0.038)	(0.016)	(0.016)
Adult participated	0.023	0.046	-0.049	0.082	0.050	-0.066	0.027	0.036
	(0.030)	(0.041)	(0.054)	(0.067)	(0.053)	(0.065)	(0.027)	(0.033)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,245	1,213	1,246	1,214	1,246	1,214	1,240	1,208
R-squared	-0.001	0.033	0.000	0.084	-0.001	0.083	-0.001	0.024
Mean (SD) dependent variable in the comparison group	0.925 (0.264)	0.925 (0.264)	0.741 (0.438)	0.741 (0.438)	0.240 (0.428)	0.240 (0.428)	0.938 (0.240)	0.938 (0.240)

Table 3.8B: Differential Impacts on Water Storage (continued)

	Water Storage							
Dependent variable:	Interior of drinking water storage container is clean		Stored drinking water container is located on a platform		Object used to fetch drinking water from storage container is clean		Water for general purposes is stored in covered containers	
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Panel A. ITT Estimation								
Child treatment	0.047***	0.040**	0.049	0.067*	0.037**	0.025*	0.064*	0.052
	(0.017)	(0.020)	(0.035)	(0.035)	(0.014)	(0.015)	(0.033)	(0.035)
Adult treatment	-0.006	0.016	-0.044	-0.102***	-0.030	-0.026	0.002	0.041
	(0.021)	(0.027)	(0.033)	(0.039)	(0.019)	(0.022)	(0.033)	(0.039)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,241	1,209	1,261	1,229	1,248	1,216	1,353	1,321
R-squared	0.005	0.021	0.004	0.136	0.008	0.021	0.003	0.080
Mean (SD) of dependent variable in the comparison group	0.904 (0.295)	0.904 (0.295)	0.440 (0.497)	0.440 (0.497)	0.931 (0.253)	0.931 (0.253)	0.548 (0.498)	0.548 (0.498)
Panel B. Instrumental variable estimation: “child participated” and “adult participated” instrumented with “child treatment” and “adult treatment”								
Child participated	0.057***	0.048**	0.059	0.083**	0.045**	0.031*	0.075*	0.060
	(0.021)	(0.024)	(0.043)	(0.042)	(0.017)	(0.018)	(0.038)	(0.041)
Adult participated	-0.010	0.026	-0.078	-0.186***	-0.052	-0.048	0.004	0.069
	(0.036)	(0.048)	(0.059)	(0.070)	(0.034)	(0.040)	(0.058)	(0.068)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,241	1,209	1,261	1,229	1,248	1,216	1,353	1,321
R-squared	0.002	0.019	-0.000	0.121	0.013	0.024	0.003	0.075
Mean (SD) dependent variable in the comparison group	0.904 (0.295)	0.904 (0.295)	0.440 (0.497)	0.440 (0.497)	0.931 (0.253)	0.931 (0.253)	0.548 (0.498)	0.548 (0.498)

Notes: Refer to Table 3.4B

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

3.3.8 Gendered Treatment Effects of Household Water Quality Testing and Information on Safe Water Behaviors

3.3.8.A Gendered Treatment Effects on Water Source Choices

In Table 3.9A, we examine the gendered treatment effects of the water quality testing and information experiment on water source choices. The study design and sampling frame allow for the analysis of gendered treatment effects. We can therefore comfortably reject any accusation of data mining. Here the results should be interpreted with caution due to missing data issues, particularly among the adult household members intervention group. Therefore, the results presented here are not as a whole and should be seen as limited evidence based on the gender of the participants. The results presented are also the differences-in-differences treatment effect estimate between male and female participants using samples from households who participated in the water quality testing and information experiment.

We find gendered treatment impacts on choice of improved main drinking water source based on WHO's JMP classification, use of other improved drinking water source based on WHO's JMP categorization on the "drinking water ladder", use of surface water also based on WHO's JMP categorization on the "drinking water ladder", and use of improved general purpose based on the JMP's classification. In all of the cases, households with male participants were worse-off than their counterparts with female participants. For instance, households with male participants were 11.5 percentage points (significant at 99 percent, without baseline household and basic school controls but not significant with baseline household and basic school controls) less likely of using improved main drinking water source (relative to the average value of 78.2 percent for households with female participants). In the case of the choice of other improved drinking water source, households with male participants were 13.3 percentage points less likely to use this water source (relative to the average value of 73.5 percent of the households with female participants). The result is robust to regression with baseline household and basic school controls. The choice of surface water as the main drinking water source was more pronounced in households with male participants in comparison with households with female participants. Households with male participants were 6.6 percentage points (significant at 95 percent, without baseline household and basic school controls but not significant with baseline household and basic school controls) more likely to use surface water as the main drinking water source (relative to the average value of 9.3 percent of the households with female participants).

Households with male participants were 10.3 percentage points less likely (significant at 95 percent, without baseline household and basic school controls but not significant with baseline household and basic school controls) to use improved general purpose water source (relative to the average value of 61.9 percent of households with female participants). We find no evidence of gendered treatment effects for other water source choice outcomes such as the use of unimproved main drinking water sources, household use of multiple drinking and general purpose water sources, use of improved secondary water sources, and use of sachet water as the main drinking water source.

Table 3.9A: Gendered Treatment Effects on Water Source Choices

	Water source choices					
Dependent variable:	Improved main drinking water based on JMP		Other improved drinking water source based on JMP		Unimproved main drinking water sources based on JMP	
	(1)	(2)	(3)	(4)	(5)	(6)
Male participated	-0.115***	-0.072	-0.133***	-0.088*	0.049	0.021
	(0.041)	(0.045)	(0.043)	(0.046)	(0.033)	(0.033)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	476	468	476	468	476	468
R-squared	0.017	0.097	0.020	0.084	0.005	0.158
Mean (SD) of dependent variable in the female participated group	0.782 (0.414)	0.782 (0.414)	0.735 (0.442)	0.735 (0.442)	0.125 (0.331)	0.125 (0.331)
	Water source choices continued					
Dependent variable:	Surface water as main drinking water source		Household reports of multiple drinking water sources		Household reports of multiple general purpose water sources	
	(7)	(8)	(9)	(10)	(11)	(12)
Male participated	0.066**	0.051	-0.037	-0.043	-0.054	-0.017
	(0.031)	(0.035)	(0.045)	(0.048)	(0.046)	(0.049)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	476	468	476	468	476	468
R-squared	0.010	0.112	0.001	0.055	0.003	0.060
Mean (SD) of dependent variable in the female participated group	0.093 (0.292)	0.093 (0.292)	0.626 (0.485)	0.626 (0.485)	0.533 (0.500)	0.533 (0.500)
	Water source choices continued					
Dependent variable:	Improved secondary drinking water source		Improved main general purpose water		Household use sachet water as the main drinking water	
	(13)	(14)	(15)	(16)	(17)	(18)
Male participated	0.033	-0.004	-0.103**	-0.060	-0.002	-0.030
	(0.054)	(0.055)	(0.045)	(0.049)	(0.037)	(0.035)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	290	283	476	468	476	468
R-squared	0.001	0.096	0.011	0.061	0.000	0.196
Mean (SD) of dependent variable in the female participated group	0.696 (0.462)	0.696 (0.462)	0.619 (0.487)	0.619 (0.487)	0.198 (0.400)	0.198 (0.400)

Notes: Refer to Table 3.4A

3.3.8.B Gendered Treatment Effects on Water Quality, Treatment and Health Risk

Table 3.9B presents the gendered treatment effects of the water quality testing and information experiment on household perceptions on water quality, treatment, and health risk. We find no evidence of gendered treatment effects for water quality, treatment, and health risk indicators.

Table 3.9B: Gendered Treatment Effects on Water Quality, Treatment and Health Risk

	Water Quality, Treatment and Health Risk							
Dependent variable:	Main drinking water source is dirty		Main general purpose water source is dirty		Satisfied with water quality		Household treat water to make it safer to drink	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Male participated	0.013	0.039	0.001	0.009	0.008	0.017	0.024	0.017
	(0.030)	(0.033)	(0.036)	(0.038)	(0.041)	(0.045)	(0.034)	(0.038)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	467	459	471	463	476	468	464	456
R-squared	0.000	0.050	0.000	0.060	0.000	0.036	0.001	0.034
Mean (SD) of dependent variable in the female participated group	0.112 (0.315)	0.112 (0.315)	0.184 (0.389)	0.184 (0.389)	0.732 (0.444)	0.732 (0.444)	0.144 (0.352)	0.144 (0.352)

Notes: Refer to Table 3.4A

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

3.3.8.C Gendered Treatment Effects on Water Transport, Collection and Handling Techniques

In Table 3.9C, we examine the effects of the gender of participants in the water quality testing and information experiment on water transport, collection and handling techniques. We find that there is limited evidence on gendered treatment effects on water transport, collection and handling techniques. The only statistically significant results we find are households with male participants spending 2.21 minutes (significant at 95 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls) less time to and from main drinking water source (relative to the average value of 10.27 minutes for households with female participants). In column 9, households with male participants are 7.5 percentage points (significant at 90 percent, without baseline household and basic school controls but not significant with baseline household and basic school controls) less likely to use children under 12 years of age in collecting water (relative to the average value of 38.9 percent for households with female participants). Other than these, household water quality testing and information experiment have no impact on water transport, collection and handling techniques. This means that the results obtained under the previous sub-sections on water transport, collection and handling techniques are not mainly influenced by the gender of participants.

Table 3.9C: Gendered Treatment Effects on Water Transport, Collection and Handling Techniques

	Water Transport, Collection and Handling Techniques					
Dependent variable:	Distance to main drinking water (in meters)		Distance to main general purpose water (in meters)		Time to main drinking water source (in minutes)	
	(1)	(2)	(3)	(4)	(5)	(6)
Male participated	24.011	25.035	6.432	3.907	-1.755	-2.210**
	(18.297)	(19.416)	(15.691)	(15.927)	(1.075)	(1.070)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	428	420	448	440	445	437
R-squared	0.004	0.060	0.000	0.056	0.006	0.095
Mean (SD) of dependent variable in the female participated group	128.692 (161.583)	128.692 (161.583)	147.363 (169.442)	147.363 (169.442)	10.273 (13.974)	10.273 (13.974)

	Water Transport, Collection and Handling Techniques			
Dependent variable:	Time to main general purpose water source (in minutes)		Children under 12 years fetch water	
	(7)	(8)	(9	(10)
Male participated	-0.361	-0.517	-0.075*	-0.046
	(1.055)	(1.027)	(0.045)	(0.050)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	448	440	459	451
R-squared	0.000	0.042	0.006	0.115
Mean (SD) of dependent variable in the female participated group	10.873 (12.619)	10.873 (12.619)	0.389 (0.488)	0.389 (0.488)

Notes: Refer to Table 3.4A

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

3.3.8.D Gendered Treatment Effects on Water Quantity and Consumption/Usage

Gendered treatment effects on water quantity and consumption are presented in Table 3.9D. While there are no statistically significant additional effects on most of the water quantity, consumption and usage indicators, we find that households with male participants consume about 9.56 liters (significant at 95 percent, without baseline household and basic school controls but not significant with baseline household and basic school controls) less of drinking water in the past two days preceding the surveys than households with female participants (Column 1). The mean in the households with female participants is 51.99 liters of drinking water in the past two days preceding the surveys. Interestingly, the volume of water for general purposes in the past two days preceding the surveys increased by 29.61 liters (significant at 90 percent, with baseline household and basic school controls but not significant without baseline household and basic school controls) (relative to the average value of 287.38 liters of the households with female participants).

Table 3.9D: Gendered Treatment Effects on Water Quantity and Consumption/Usage

	Water Quantity and Consumption/Usage			
Dependent variable:	Volume (liters) of drinking water consumed (past 2 days)		Volume (liters) of general purpose water consumed (past 2 days)	
	(1)	(2)	(3)	(4)
Male participated	-9.562**	-5.753	15.181	29.605*
	(4.774)	(4.892)	(16.213)	(16.358)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	473	465	475	467
R-squared	0.008	0.075	0.002	0.146
Mean (SD) of dependent variable in the female participated group	51.986 (69.472)	51.986 (69.472)	287.383 (141.366)	287.383 (141.366)

Notes: Refer to Table 3.4A

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

3.3.8.E Gendered Treatment Effects on Water Storage

Table 3.9E presents the gendered treatment effects on water storage. We do not find evidence of the effects of the gender of participants on most of the water storage behavior indicators. In column 13, households with male participants are 4.8 percentage points less likely of having the interior of drinking water storage container observed to be clean (relative to the average value of 95 percent of the households with female participants). The result is robust to regressions including baseline covariates (column 14). The result in column 19 shows that households with male participants are 10.5 percentage points less likely of having water for general purposes stored in covered containers (relative to the average value of 62.5 percent of the households with female participants).

Table 3.9E: Gendered Treatment Effects on Water Storage

	Water Storage							
Dependent variable:	Usually stock drinking water in the house		Container is set on the ground		Container closed by a lid or cork		Used soap or detergent to wash container the last time	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Male participated	-0.022	-0.008	0.031	0.009	0.008	0.007	-0.047	-0.047
	(0.034)	(0.034)	(0.050)	(0.051)	(0.025)	(0.026)	(0.047)	(0.048)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	475	467	399	391	399	391	399	391
R-squared	0.001	0.186	0.001	0.178	0.000	0.044	0.003	0.167
Mean (SD) of dependent variable in the female participated group	0.852 (0.356)	0.852 (0.356)	0.553 (0.498)	0.553 (0.498)	0.931 (0.254)	0.931 (0.254)	0.716 (0.452)	0.716 (0.452)

	Water Storage							
Dependent variable:	Used only plain water in washing the container the last time		Drinking water storage container is covered		Interior of drinking water storage container is clean		Stored drinking water container is located on a platform	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Male participated	0.023	0.035	0.018	0.012	-0.048*	-0.056*	0.003	0.029
	(0.046)	(0.047)	(0.020)	(0.022)	(0.027)	(0.030)	(0.050)	(0.048)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	399	391	401	393	402	394	409	401
R-squared	0.001	0.161	0.002	0.063	0.009	0.056	0.000	0.187
Mean (SD) of dependent variable in the female participated group	0.275 (0.448)	0.275 (0.448)	0.950 (0.219)	0.950 (0.219)	0.950 (0.219)	0.950 (0.219)	0.453 (0.499)	0.453 (0.499)

Table 3.9E: Gendered Treatment Effects on Water Storage (continued)

	Water Storage			
Dependent variable:	Object used to fetch drinking water from storage container is clean		Water for general purposes is stored in covered containers	
	(17)	(18)	(19)	(20)
Male participated	-0.017	-0.023	-0.105**	-0.082*
	(0.025)	(0.027)	(0.046)	(0.049)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	402	394	461	453
R-squared	0.001	0.053	0.011	0.090
Mean (SD) of dependent variable in the female participated group	0.941 (0.237)	0.941 (0.237)	0.625 (0.485)	0.625 (0.485)

Notes: Refer to Table 3.4A

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

3.4. Conclusions

Using a cluster-randomized evaluation design, this chapter examined the impacts of granting households in southern Ghana the option of water quality self-testing and information. The chapter answers an important question of does water quality testing and information increases safe water behaviors i.e. risk avoidance behavior of poor water quality? The study also provides evidence of the importance of intrahousehold resource allocation or decision making on the dissemination of water quality information. Households in southern Ghana were randomly given water quality testing toolkits and information on water quality improvement. The treatment group was separated into two groups: an intervention run on school children (i.e. child treatment) and one run on adults (i.e. adult treatment). The methods applied in this study are rigorous to identify changes in safe water behaviors. The baseline household data are largely balanced based on the summary statistics and mean orthogonality tests. We find that there is high participation rate or take-up, with about 71 percent of the households engaging in water quality self-testing and also receiving water quality improvement messages (information), after being encouraged to attend the training sessions on water quality testing. The participation rate was high for school children intervention group compared to the adult household members intervention group. The participation rate was slightly higher for females than males. The differences in uptake show different roles played by different actors on resource allocation or decision making in many traditional households in southern Ghana.

After three follow-up surveys conducted in 2014 and 2015, we find evidence of changes in safe water behaviors. Specifically, we find evidence of increases in making cash-intensive water source choices; declines in using surface water sources; making time gains in looking for safer water sources; increases in knowledge and awareness on water safety; declines in using child labor in water collection; and increases in safe water storage behaviors such as covering of stored drinking water. While treated households undertake many safe water behaviors, there is less treatment of water. One possible explanation is that in the study context, we find that households opted for the safest option (i.e. sachet/bottled water) based on the microbial analysis. Therefore, households switched from cheap, long distance sources to the closer, expensive ones. In addition, limited options in water treatment in the study sites may also be contributing factor to less water treatment. The result of water treatment is also consistent with Hamoudi *et al*., (2012) in which water quality testing and information lead no statistically significant changes in household water treatment. The findings show that household water quality testing and information could be used as a social marketing strategy in convincing households in resource poor settings in adopting safe water behaviors.

Differential impacts exist with households in the school children intervention group being better-off in most of the safe water behavior indicators than their counterparts in the adult household members intervention group is. Generally, statistically significant treatment effects come from the child treatment, not the adult treatment. In comparison with the adult treatment, treating school children leads to: more use of improved drinking water; less use of surface water as main source; more sachet water use; less treating of water; less distance to the main source of water; no real change in volume of water consumed; more closing and covering of containers, more clean containers and clean fetching equipment. The differential impacts also show different perception and knowledge on water quality for the two treatment groups. The results are in tandem with the different water source choices based on the treatment groups. In the study sites, there are multiple sources of water. Therefore, the trade-off between water sources as result of the intervention generated considerable time gain in terms of distance and minutes saved on water collection trips. The results suggest that school children could be used as "agents of change" in improving safe water behaviors in many developing countries. This partly confirms a previous prospective study by Onyango-Ouma *et al.,* 2005 on the potential of using school children as "agents of change" in health.

A policy relevant question that arises is why school children are better at changing the behavior of their households rather than parents are at changing their own behavior and that of the household? In this study context, children play various roles in the household including (1) providing labor and time in collecting/fetching water and also performing other household chores and (2) disseminating information on water quality to households. In both cases, greater knowledge leads to collecting water from high-quality sources and raising awareness on the importance of choosing averting behavior. In many developing countries with high illiteracy rate, school children could be an important source of information. Therefore, school children play critical roles in safe water behaviors and are not "passive" members of the households. In this study context, the learning experience of children was enough in convincing their parents and other household members to adopt safe water behaviors. In addition, parents/adults may be preoccupied with other social and economic issues and their experiences, illiteracy, previous knowledge and perceptions on water quality may hinder assimilation of the experiment.

These results have implications on the Sustainable Development Goals, particularly on improvement in safe water behaviors and microbial analysis of water quality by providing practical experiences from resource poor settings. Finally, we also find limited evidence based on the gender of participants, with households with male participants in most cases being worse-off than households with female participants. In other words, less is achieved by treating males. Improvement in safe water behaviors could be achieved by targeting females instead of males. The policy implication is that traditional or cultural barriers in many developing countries on gender differentiated roles on household or domestic chores need to be addressed in order to improve safe water behaviors.

Chapter 4. Household Water Quality Testing and Information: Identifying Impacts on Health Outcomes, and Sanitation and Hygiene-related Risk-mitigating Behaviors

4.1 Introduction

Globally, consumption of unsafe water affects about 663 million people (UNICEF and WHO, 2015) and in 2012 caused about 502,000 diarrhea deaths among children under five years of age in developing countries (Prüss-Ustün *et al*., 2014). Several interventions have been designed and implemented to address the use of unsafe water and its associated effects on diarrhea occurrences in many developing countries and these measures can be categorized into two broad areas: (1) "hardware interventions" and (2) "software interventions" (Varley *et al*., 1998; Waddington *et al.,* 2009). In the case of water supply, "hardware interventions" involve the provision of physical infrastructure such as piped water supply, boreholes or protected wells to communities while "software interventions" usually target household safe water behaviors by providing information and education to households on the essence of using safe water.

A systematic review by Waddington *et al.,* (2009) using studies that applied experimental and quasi-experimental approaches, showed that water, sanitation and hygiene interventions are effective in reducing the prevalence of diarrhea among children in developing countries. They found that both "software interventions" and "hardware interventions" are all effective in reducing diarrhea rates in children. Comparing point-of-use (POU) water quality interventions, and water supply and source treatment (POS) interventions, the former was more effective than the later but most of the trials have been conducted in areas with low population density and also for short time durations. Furthermore, promotion of good hygienic behavior through hand-washing with soap ("software interventions") and provision of sanitation facilities ("hardware interventions") were effective in dealing with the incidence of diarrheal diseases. Cairncross *et al.,* (2010), in a systematic review of the literature on the effect of using different types of interventions, concluded that "hand washing with soap, improved water quality and excreta disposal" interventions were associated with a reduction of diarrhea risk by about 48, 17 and 36 percent respectively for each of the interventions. Clasen *et al*., (2007) showed that in general interventions to improve water quality are effective in averting the occurrences of diarrhea among all ages including children under five years of age. On the contrary, Colford *et al.,* (2005) conducted a randomized controlled trial (RCT) intervention with "blinding" in United States of America (USA) and found that there was no recognizable decrease in gastrointestinal illness after the introduction of "in-home use of a device designed to be highly effective in removing microorganisms from water."

In the direction of the "software interventions" or of the supply of "information and education", existing studies highlight that households in poor resource settings consume contaminated water sources due to the lack of adequate information on the quality of different water sources. Interestingly, several studies have examined the role of information in addressing the choice and use of safe water sources (Madajewicz *et al*., 2007; Hamoudi *et al*., 2012; Brown *et al*., 2014; and Jalan and Somanathan, 2008). One peculiar characteristic of water quality information, unlike other products, is the requirement for some form of "formal" testing to determine the type of contaminants present in a given sample. Furthermore, in recent times several studies have provided a better understanding of the role of information in achieving safe water behaviors, including the use of improved water sources, water treatment, safe storage, and transport. According to Luoto *et al*. (2014), "price and information matter" when it comes to achieving safe water behaviors. Their study in Kenya and Bangladesh shows that health risk messages on the relevance of safe drinking water delivered consistently over time increase the use of water treatment products and other safe water behaviors. A study by Madajewicz *et al*., (2007) shows that the dissemination of information on arsenic contaminated wells to households in Bangladesh leads them to switch to water from safe wells. Jalan and Somanathan (2008) conducted a study on the dissemination of information to households, in India, on fecal contamination of water at the point-of-use (POU). The study finds that households not previously treating water increased their likelihood of undertaking water treatment. Hamoudi *et al*., (2012) find that presenting evidence of fecal contamination of household water sources increases demand for clean water from commercial sources.

Even though the impacts of household water quality testing and information on health outcomes and on sanitation and hygiene-related risk-mitigating behaviors may seem direct, there have been few studies on this topic. More importantly, the application of rigorous impact evaluation is limited (Lucas *et al*., 2011). In particular, the random allocation of households to the water quality self-testing and information intervention into the various treatment groups (i.e. control versus treatment) is necessary to avoid selection bias (Finkelstein *et al*., 2012). Such studies that guarantee robust results are few, especially those investigating impacts on health outcomes, and on sanitation and hygiene behaviors.

In this study, we examine the impacts of a household water quality testing and information experiment on health outcomes and sanitation and hygiene-related risk-mitigating behaviors. So far, water quality improvement, choice of improved water sources and other safe water behaviors have been the main focus of the literature on household water quality testing and information interventions (Madajewicz *et al*., 2007; Hamoudi *et al*., 2012; and Jalan and Somanathan, 2008;). Expanding the analysis to include impacts on health outcomes and sanitation and hygiene-related risk avoidance behaviors is our main contribution, particularly in the context of multi-use water systems. We achieve this aim by analyzing three follow-up surveys undertaken after one, three months and seven months of households performing water quality self-testing and receiving water quality improvement messages in the form of handouts. Furthermore, we compare the impacts of the different vectors of change - the intervention arms: adult household members and school-going children. Only one existing study (Brown *et al*., 2014) analyzed the effects of household water quality testing and information on diarrhea rates and other health risks, but this study was based on single arm treatment design. In this study, we analyze the impacts on health, and on sanitation and hygiene behaviors in a multi-arm randomized evaluation design in order to identify the best channel for the delivery of household water quality information. In addition, we have expanded the analysis to include additional indicators on child health and nutrition, sanitation and hygiene behaviors such as child height, child weight, child body mass index, cleanliness of dwelling, neatness of household members, among others.

We start by presenting the baseline comparison of means between treatment groups (those selected for the water quality self-testing and information experiment) and the comparison group (non-participants in the water quality self-testing and information). We then estimate the treatment effects of the water quality self-testing and information intervention on a wide range of health outcomes, and sanitation and hygiene-related risk-mitigating behaviors, using the random allocation into treatment groups as instruments.

The analyses of the treatment effects have been structured under two broader themes: (1) impacts on health outcomes and, (2) impacts on sanitation and hygiene-related risk-mitigating behaviors. In terms of the health outcomes, we study the impacts on the prevalence of diarrhea, malaria, self-reported illnesses, and overall well-being. There is also a separate analysis dedicated only to impacts on child health and nutrition outcomes. In relation to sanitation and hygiene-related risk-mitigating behaviors, we analyzed the impacts of the water quality self-testing and information experiment on diarrhea prevention knowledge, sanitation and hygiene practices (for example handwashing with soap), and cleanliness of households. The hypotheses we test are that the water quality self-testing and the dissemination of information on water quality improvement to households improve sanitation and hygiene-related risk-mitigating behaviors. Eventually, this is in turn expected to lead to improvement in health and nutrition outcomes, even though the seven months gap between the intervention and the final surveys may be too short to identify changes in nutrition outcomes.

After seven months of household water quality testing and information experiment, we find generally mixed evidence. On one side, being randomly selected into the household water quality testing and information experiment is associated with 71.2 percentage points participation or uptake rate, which is primarily attributable to our intervention since at the time of our study there was no market or another type of exercise being undertaken in the study sites. The high household uptake rate may indicate the households' high willingness to participate in new technologies on how to improve water quality. On the other hand, we find only a little evidence of the impacts of the intervention on health outcomes and sanitation and hygiene-related risk-mitigating behaviors. These impacts appear mostly when we differentiate across treatment arms, (i.e. school children versus adult members of the household). We also find very limited evidence of differentiated impacts across the gender of the participants (male versus female students, or male versus a female adult member of the household).

The rest of the study is structured as follows. Section 4.2 describes the household water quality testing and information experiment, randomization process and data sources. Section 4.3 provides the estimation strategy. Section 4.4 presents results and discussion. Section 4.5 concludes the study.

4.2. Study Settings, Experimental Design, Data Collection and Summary Statistics

This section describes the study settings, study design, data sources and summary statistics.

4.2.1 Study Settings

We collaborated with the Institute of Statistical, Social and Economic Research (ISSER) of the University of Ghana, Legon from July 2013 to June 2015 to study 512 randomly sampled households in 16 communities and their environs in the Ga South Municipal and Shai-Osudoku district in the Greater Accra region of Ghana. The region is the most densely populated region in Ghana. The two districts (study sites) were selected because the communities are largely located in multi-purpose water settings. Multipurpose water system is defined loosely as location or presence of water resources being used for more than one purpose. In this context, we defined multipurpose water systems to include localities or areas with lakes or streams or rivers being used as drinking or general purpose water sources and for irrigated agriculture or fishing purposes. For Ga South Municipal, communities and public basic schools in the Densu river catchment area were targeted. The Ga South municipal is also bordered by the sea (Gulf of Guinea). In the case of Shai-Osudoku district, we targeted communities around/along the Volta River (see Figure 2.1 for a map of the study sites). Communities in the two sites rely on unimproved sanitation while the use of improved water sources is fairly high. Water source choices among households are diverse including the use of sachet/bottled water, standpipe, borehole, rain water, canals, rivers/streams/lakes, etc. Household's use of multiple water sources is moderately high.

4.2.2 Experimental Design and Sample Selection

We conducted an institutional survey with public basic schools, and water and sanitation (WATSAN) management committees in the two selected districts to identify communities based on the inclusion criteria of having irrigated fields, and fishing waters, and use of unimproved sanitation and water sources. The institutional survey resulted to interviews with 48 public basic schools and 35 WATSAN committees. 16 out of the 48 public basic schools were selected for the study. Complete public basic schools (i.e. public basic schools with both primary and junior high) were selected for the study. In each community, one public basic school was selected (i.e. 16 public basic schools in 16 communities). We obtained the student register for students from grade 5 to 8 in each public basic school; which sums to 4651 student population. From this list, 512 students (i.e. 32 students per public basic school) were randomly selected using STATA version 12.1 software. Each selected student represented one household. The sampling procedure controlled for grade and gender of the students. In each grade, we randomly selected equal proportions of boys and girls. To account for the selection of siblings, a random draw from the student list as replacement list was generated.

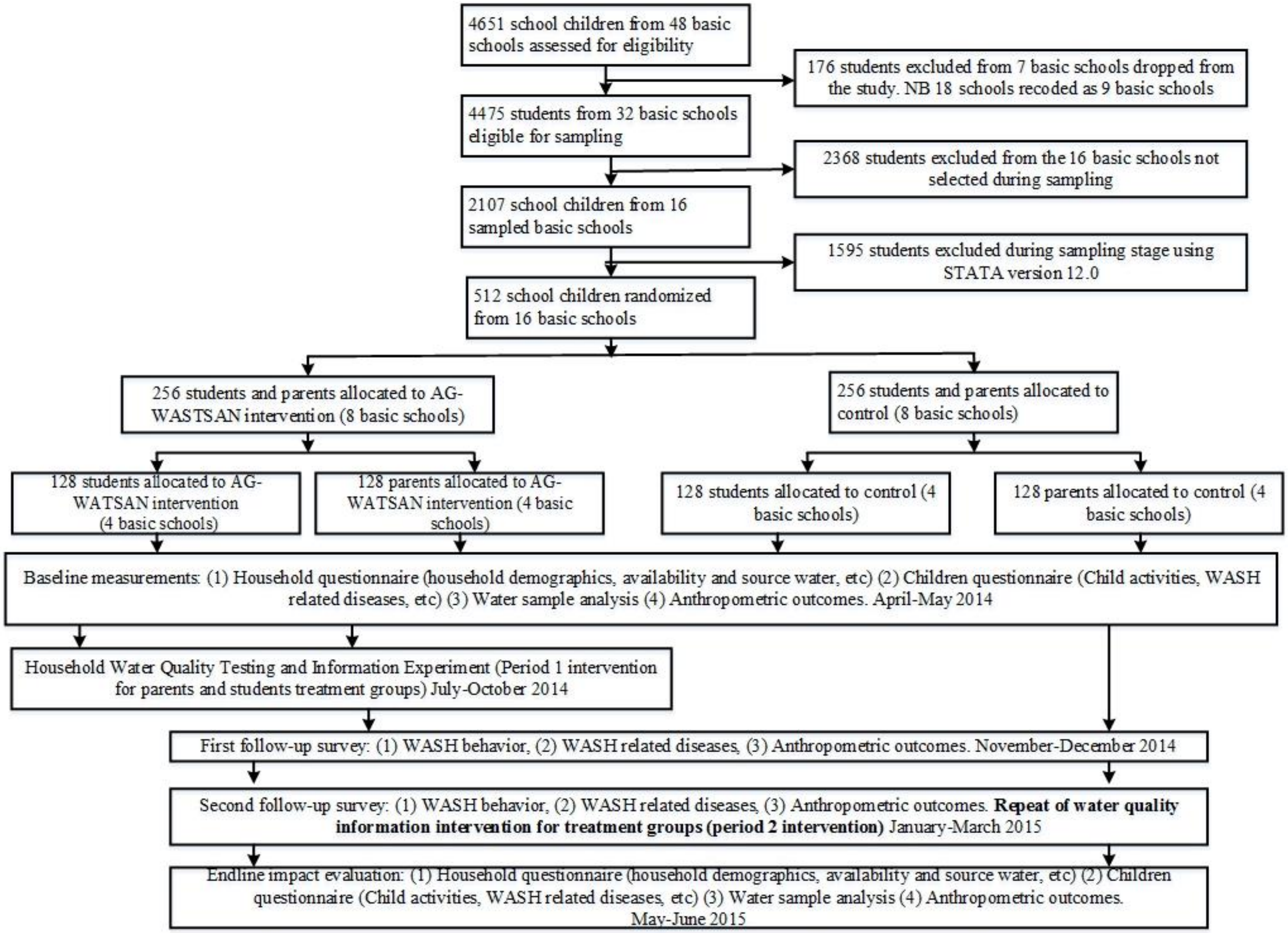
The study applies a cluster-randomized evaluation design. To avoid contamination (or spillovers) of the intervention, public basic schools (or communities) that are at least 3 kilometers apart were selected. This distance based on our estimation was enough to prevent spillovers since the majority of the students travel on foot to their various schools. Furthermore, we include questions on the details of the intervention in the follow-up surveys and our analysis shows that none of the households in the comparison group had detailed information concerning the treatment. This complemented by the short duration of the household surveys should provide the requisite barrier to information flow between the treatment and control groups. After completion of the sampling procedure, the 16 selected public basic schools were randomly allocated into the treatment and control groups. Four public basic schools each were randomly allocated into the school children intervention group, school children control group, adult household members intervention group and lastly, adult household members control group. We applied third party randomization, by using someone who has no interest in the study and has no idea of the study sites to conduct the randomization process. This was also to achieve the basic principles of randomization such as "masking, blinding and concealing" (Viera and Bangdiwala, 2007; Torgerson and Roberts, 1999). Although third party randomization generates a "purely" or "truly" randomized study, there is also a risk of obtaining data, which are not similar across the study sites, especially among studies with smaller samples. This could be controlled during data analysis by including baseline covariates as robustness checks. For all analysis, we combined the two control groups (i.e. school children control group and adult household members control group) as one and redefined it as a comparison group.

In March 2014, we conducted a household tracking/listing exercise to confirm the selected households and students. Selected siblings from the same households and dropped-out students were replaced with students from our replacement list. We used the tracking/listing exercise to seek the consent and assent from the participating households and students, respectively.

Two months after the completion of the baseline survey (July 2014), we rolled-out the intervention for the two treatment groups (i.e. school children intervention group and adult household members intervention group). In the school children intervention group as the name suggests we used school children for the intervention and in the adult household members intervention group we relied on adult household members (such as husband/father and wife/mother) for the intervention. Note that public basic schools are the unit of randomization. So for public basic schools selected as the adult household members intervention group instead of the selected students who represented the households, we used their parents/guardians/relatives. The selected boys were represented by the fathers (household heads) or adult males from the household and the girls were represented by their mothers (spouse) or adult females from the households. We allowed for delegation in the adult household members intervention group since not all parents/guardians could be available for the experiment. Selected households were informed about the water quality self-testing intervention through the school authorities. In the case of the adult household members intervention group, the information was relayed to them through the school children.

The round one of the intervention involved two phases. The first phase involved group-based training on the use of the water testing kits. Hired assistants (community health nurses) completed this in July 2014. The second phase involved actual water quality self-testing which was completed in October 2014. The delay in executing the water quality self-testing intervention was primarily due to administrative and logistical constraints. We developed nine water quality improvement messages in the form of hand-outs based on previous studies (Brown *et al.,* (2014) and Hamoudi *et al.,* (2012)) and these were distributed to the participating households. The recommended behaviors for the households were: (1) obtaining drinking and general purpose water from safe sources such as standpipe, borehole, protected well, sachet/bottled water, rain water, and protected spring; (2) chemically treating, boiling or filtering water or use advanced filters; (3) storing drinking water for not more than a day before drinking it; (4) transporting water in covered containers/pans/vessels; (5) washing hands with soap frequently; (6) washing storage containers between uses; (7) avoiding direct hand contact with drinking water; (8) securely covering all water storage containers; and (9) keeping water out of the reach of children. In October-November 2014, water samples from both point-of-source (POS) and point-of-use (POU) in the comparison group were collected and analyzed by hired field assistants using the same water testing kits used by the intervention groups. In March 2015, hired field assistants revisited all the participating households (both school children and adult household members) to redeliver the same water quality improvement messages (i.e. round two experiment). Then two copies of the hand-outs containing the water quality improvement messages were left with the households for reference and also discussions with other household members. The randomization design, timeline of the experiment and data collection are presented in Figure 4.1. The detailed experimental design is described in Chapter three.

Figure 4.1: Flowchart of Randomization Design and Timelines



4.2.3 Data Collection and Summary Statistics

In the 512 randomly selected households from the 16 communities, a socio-economic survey in addition to water sample analysis (both laboratory and on-field) of both POS and POU was undertaken in April-May 2014. In April-May 2014, hired field data collectors visited the households to conduct baseline interview with the household heads or adults who are most knowledgeable on water, sanitation and hygiene issues (for instance, spouse). In all, the baseline survey yielded interviews with 505 households, a success rate of 98.6 percent. The baseline survey involved asking respondents for information on current water, sanitation and hygiene behaviors. The baseline survey also captured detailed information on socio-economic characteristics. Anthropometric measurements for children under eight years of age were also undertaken during the baseline data collection.

One month after the water quality self-testing and information intervention (November 2014), we conducted the first follow-up survey on key water, sanitation and hygiene behaviors, and health indicators. We also took anthropometric measurements of all children under eight years of age at baseline or born after the baseline survey. This was completed in December 2014. The first follow-up survey yielded interviews with 486 households. Between January and February 2015 (i.e. three to four months after the intervention), we conducted the second follow-up survey using the same instruments as the first follow-up survey. We successfully interviewed 478 households. Finally, in May-June 2015 (i.e. about two to three months after completion of round two experiment) we completed the endline survey using largely the baseline survey instruments. At the end of the endline survey, we successfully enumerated 437 households. Overall attrition rate is moderate: about 97.2 percent of the households interviewed during baseline survey was successfully enumerated in at least two out of the three follow-up surveys while about 82.4 percent of the households were enumerated in all three follow-up surveys.

Using a procedure previously applied by Karlan *et al*., 2014, we assess the statistical similarity of the households in the study arms at the baseline. Summary statistics and mean orthogonality tests are presented in Table 4.1. We show the *F*-test of each covariate among the three study arms (results in Column 5) and report *p*-value, which tests the null hypothesis of no statistically significant difference from each study arm. In the last but one row of each table (except Table 4.1, Panel D), we report *F*-test and *p*-value of a regression of each of the study arms on all the covariates in the table. Most of the household health outcomes, and sanitation and hygiene-related risk-mitigating behaviors are similar across the study arms (Table 4.1). Out of 41 *F*-tests reported in Table 4.1, 10were statistically significantly different from zero at the various confidence levels.

Due to space reasons, we will not present the summary statistics and mean orthogonality tests for household socio-economic characteristics. The socio-economic characteristics, which are used as baseline household and basic school covariates in the impact analyses, are presented in detail in Chapter three. The socio-economic characteristics are extremely similar across the three study arms. These baseline covariates have been reported in the Tables for the impact analyses.

We briefly mention here some of the most interesting facts observed in Tables 4.1. At baseline, about 90.4 percent of the households reported handwashing with soap or detergent (Table 4.1, Panel A). About 33.7 percent of the households have latrine/toilet in their dwelling (Table 4.1, Panel A). About 83.4 percent of the households had latrine/toilet, which was very clean or clean enough based on enumerator observations (Table 4.1, Panel A). Malaria cases are high with about 35.2 percent of the households reporting at least one case in the past one month preceding the survey while diarrhea rate is low with 15.4 percent of the households reporting at least one case in the past one month preceding the survey (Table 4.1, Panel D).

Table 4.1: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel A: Sanitation and Hygiene Practices					
Last time respondent used soap/detergent to wash hands (Self-reported)	0.848 (0.016)	0.875 (0.030)	0.855 (0.032)	0.831 (0.025)	**0.587** **(0.568)**
Child is wearing shoes/slippers	0.743 (0.020)	0.802 (0.036)	0.681 (0.044)	0.743 (0.028)	**1.417** **(0.273)**
Clothes of child are dirty/very dirty	0.242 (0.020)	0.207 (0.037)	0.293 (0.042)	0.236 (0.027)	**1.842** **(0.193)**
Face and hands of child are dirty/very dirty	0.211 (0.019)	0.124 (0.030)	0.267 (0.041)	0.228 (0.027)	**3.085*** **(0.076)**
Surrounding of household is clean/average	0.856 (0.016)	0.855 (0.032)	0.866 (0.030)	0.852 (0.023)	**0.0389** **(0.962)**
Latrine or toilet is very clean/clean enough	0.834 (0.029)	0.855 (0.048)	0.821 (0.062)	0.826 (0.046)	**0.109** **(0.897)**
Respondent mentioned at least three instances of handwashing yesterday	0.911 (0.013)	0.928 (0.023)	0.953 (0.019)	0.881 (0.020)	**0.724** **(0.501)**
F-test (p-value) from regression of each study arm on all above covariates		**1.307** **(0.313)**	**1.041** **(0.438)**	**1.767** **(0.174)**	
Observations (N)	**505**	**125**	**127**	**253**	

Notes. Clustered standard errors are presented in parenthesis. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable. Latrine cleanliness is dropped in the analysis for final analysis in the last but one row, since not all households have latrine or toilet. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 28 tests in total for sanitation and hygiene practices.

Table 4.1: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey) (continued)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel B: Diarrhea Prevention Knowledge					
Respondent names handwashing as the best way to prevent diarrhea	0.512 (0.023)	0.374 (0.045)	0.607 (0.045)	0.531 (0.032)	**11.41***** **(0.001)**
Respondent names use of clean drinking water as the best way to prevent diarrhea	0.381 (0.022)	0.478 (0.047)	0.274 (0.041)	0.387 (0.031)	**10.77***** **(0.001)**
F-test (p-value) from regression of each study arm on all above covariates		**4.226**** **(0.035)**	**3.419*** **(0.060)**	**2.346** **(0.130)**	
Observations (N)	**505**	**125**	**127**	**253**	

Notes. Clustered standard errors are presented in parenthesis. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 8 tests in total for diarrhea prevention knowledge.

Table 4.1: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey) (continued)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel C: Overall Well-being and Health					
Household member purchased any medicine or medical supplies in the past 4 weeks	0.172 (0.007)	0.190 (0.015)	0.171 (0.014)	0.164 (0.010)	**0.354** **(0.708)**
Household member had diarrhea in the past 4 weeks	0.033 (0.003)	0.041 (0.007)	0.035 (0.007)	0.028 (0.004)	**0.318** **(0.733)**
Household member reported any illness or injury in the past 4 weeks	0.169 (0.007)	0.187 (0.014)	0.177 (0.014)	0.156 (0.009)	**1.381** **(0.281)**
Overall, the respondent rates health of household members as very healthy/somewhat healthy	0.957 (0.004)	0.944 (0.008)	0.960 (0.007)	0.962 (0.005)	**0.202** **(0.820)**
F-test (p-value) from regression of each study arm on all above covariates		**0.671** **(0.622)**	**0.367** **(0.829)**	**0.606** **(0.664)**	
Observations (N)	**3,072**	**764**	**744**	**1,564**	

Notes. Clustered standard errors are presented in parenthesis. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 16 tests in total for overall well-being and health.

Table 4.1: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey) (continued)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel D: Malaria Fever and Diarrhea Illnesses					
Household reported at least one malaria case in the past 2 weeks	0.180 (0.017)	0.128 (0.030)	0.189 (0.035)	0.202 (0.025)	**2.249** **(0.140)**
Household reported at least one malaria case in the past 4 weeks	0.352 (0.021)	0.344 (0.043)	0.362 (0.043)	0.352 (0.030)	**0.0178** **(0.982)**
Household reported at least one diarrhea case in the past 2 weeks	0.119 (0.014)	0.136 (0.031)	0.110 (0.028)	0.115 (0.020)	**0.063** **(0.940)**
Household reported at least one diarrhea case in the past 4 weeks	0.154 (0.016)	0.168 (0.034)	0.157 (0.033)	0.146 (0.022)	**0.044** **(0.957)**
Observations (N)	**505**	**125**	**127**	**253**	

Table 4.1: Baseline Descriptive Statistics and Orthogonality Tests, Mean (April-May, 2014 Survey) (continued)

	(1) All	(2) Child treatment	(3) Adult treatment	(4) Comparison group	(5) F-test (p-value) from regression of variable on child treatment and adult treatment
Panel E: Child Health and Nutrition					
Child age (years)	3.606	3.350	3.544	3.766	**3.635***
	(0.099)	(0.203)	(0.187)	(0.143)	**(0.052)**
Gender of child (male=1)	0.520	0.470	0.573	0.517	**3.453***
	(0.025)	(0.050)	(0.049)	(0.035)	**(0.058)**
Child had diarrhea in the past 4 weeks indicator	0.062	0.070	0.039	0.070	**0.703**
	(0.012)	(0.026)	(0.019)	(0.018)	**(0.511)**
Child had malaria in the past 4 weeks indicator	0.163	0.170	0.194	0.144	**0.302**
	(0.018)	(0.038)	(0.039)	(0.025)	**(0.744)**
Child height (cm)	97.26	95.48	94.41	99.61	**5.513****
	(0.910)	(1.884)	(1.732)	(1.272)	**(0.016)**
Child weight (kg)	14.71	14.27	14.07	15.26	**3.485***
	(0.248)	(0.488)	(0.476)	(0.356)	**(0.057)**
Child body mass index (BMI) (kg/m^2)	15.38	15.55	15.61	15.18	**1.807**
	(0.112)	(0.267)	(0.235)	(0.133)	**(0.198)**
Height-for-age *z*-score	-1.191	-1.175	-1.427	-1.084	**0.820**
	(0.0810)	(0.178)	(0.153)	(0.111)	**(0.459)**
Weight-for-age *z*-score	-0.846	-0.822	-0.953	-0.807	**0.853**
	(0.0647)	(0.133)	(0.125)	(0.092)	**(0.446)**
Weight-for-height *z*-score	-0.348	-0.329	-0.227	-0.424	**1.367**
	(0.0748)	(0.162)	(0.160)	(0.096)	**(0.285)**
Body-mass-index-for-age z-score	-0.169	-0.135	-0.033	-0.255	**1.838**
	(0.0776)	(0.190)	(0.153)	(0.095)	**(0.193)**
Overall, the respondent rates health of child as very healthy/somewhat healthy	0.942	0.938	0.951	0.938	**0.109**
	(0.012)	(0.0248)	(0.021)	(0.017)	**(0.897)**
F-test (p-value) from regression of each study arm on all above covariates		**0.707**	**1.001**	**2.623***	
		(0.667)	**(0.468)**	**(0.055)**	
Observations (N)	**404**	**100**	**103**	**201**	

Notes. Clustered standard errors are presented in parenthesis. The total sample for the columns (1)-(5) may vary based on missing data for each outcome variable. Additional tests (not reported here) are performed for pairwise comparison of the covariates for the treatment and comparison groups. *T*-tests of any treatment vs. control groups (1 test), each individual study arm vs. another arm (3 tests), making a total of 4 tests per covariate, and then 48 tests in total for child health and nutrition. Dropped child BMI, height-for-age *z*-score, weight-for-age *z*-score, weight-for-height *z*-score, and body-mass-index-for-age z-score indicators for the F-test (p-value) from a regression of each study arm on all above covariates because it is related to height and weight variables. Regressions for child height, weight and BMI are restricted for only those children (samples) without outliers by using the STATA *bacon* command.

4.3. Estimation Strategy

First, we estimate the reduced form of the effect of the household water quality testing and information experiment which provides the comparison of means between the intervention group and the comparison group (those not assigned to the household water quality testing and information). Based on the experimental evaluation design already described under section 4.2.2, the reduced form basic equation could be specified as:

(7) $Y_{it} = \alpha + \beta_1 T_{it} + X_{it}^{'} \delta + \varepsilon_{1it}$

where i represents an individual/household and time $t(t \in \{1,2,3\}$ for the three follow-up survey rounds (waves). Y_{it} is the outcome variable of interest (for instance, handwashing with soap) and T_{it} is a dummy variable representing 1 if household was assigned to household water quality testing and information experiment (i.e. either school children intervention group or adult household members intervention group). $X_{it}^{'}$ is a set of baseline household and basic school characteristics, which is used in some of the specifications as robustness checks while ε_{1it} is the disturbance term. β_1 indicates the average differences between treatment and comparison groups for the respective outcome variables; which is the intention-to-treat (ITT) estimate. The reduced form (ITT) parameter derived from Equation (7) estimates the causal effect of being assigned to household water quality testing and information experiment.

Second, we estimate another set of equation(s) on the impacts of actually participating in the household water quality testing and information intervention. This is based on the premise that even if the water quality self-testing and information package are provided free of charge, not all households will make themselves available for the exercise. Further participation (represented as P_{it} in Equation (8)) may be affected by inability to fully comply with the water quality testing protocols. The causal effect of participation in the household water quality testing and information on a wide range of outcome variables is specified with an equation analogous to:

(8) $Y_{it} = \delta_0 + \beta_2 P_{it} + X_{it}^{'} \pi_1 + v_{it}$

Equation (8) is estimated using two stage least squares (2SLS), with the first stage equation being specification analogs to:

(9) $P_{it} = \pi_2 + \pi_3 T_{it} + X_{it}' \pi_4 + u_{it}$

where the excluded instrument is T_{it} the treatment allocation variable with π_3 being the first stage coefficient. The underlining assumption for the 2SLS is that selection into the treatment arm had impact on the outcome variables through actual participation. The 2SLS estimator is interpreted as the instrumental variable (IV) estimation or local average treatment effect (LATE). Practically, we expect the ITT estimation and the LATE (or IV) estimation to be similar since the first stage coefficient is very strong.

Third, we explore the heterogeneous/differential impacts of the intervention as a function of the treatment arms. We suspect that the treatment effects may vary depending on the treatment arms and this estimation is performed using regression analogs to:

(10) $Y_{it} = \mu_0 + \beta_3 C_{it} + \beta_4 A_{it} + X_{it}^{'} \pi_5 + \varepsilon_{2it}$

where C_{it} is a dummy variable that household i was assigned to school children intervention group in time t and A_{it} is an indicator variable that the household i was assigned to adult household members intervention group in time t. $X_{it}^{'}$ is a vector of baseline household and basic school covariates included in some specifications as sensitivity analyses. We study the impacts of participation by the treatment arms by applying IV or LATE estimation strategy with the random assignment into the treatment arms used as instruments.

Fourth, we complete our analyses by estimating the gendered treatment effects of participation using differences-in-differences (DID) estimator with regression analogous to:

(11) $Y_{it} = \mu_1 + \beta_5 M_{it} + X_{it}^{'} \pi_6 + \varepsilon_{3it}$

where M_{it} is a dummy variable that household i had a male participant in the household water quality testing and information experiment. All the equations are estimated using linear approximation although most of the outcome variables are binary. We report robust standard errors for all the analyses and, finally, all datasets are unweighted.

4.4. Results and Discussion

This section presents the results and discussion on the impacts of household water quality testing and information experiment on the health outcomes, and sanitation and hygiene-related risk-mitigating behaviors.

4.4.1.A. Impacts on Sanitation and Hygiene Practices

Using a regression with specifications analogous to Equation (7), we estimate the impacts of household water quality testing and information on sanitation and hygiene practices. We include in some specifications baseline household and basic school covariates such as head's age, the head is married, household resides in the urban district, school contact person is a male, among others. We report robust standard errors. Panel A of the Tables reports the ITT estimation while Panel B reports the IV estimation. The IV specification is estimated using a 2SLS with the random assignment into the treatment arm(s) as instruments. The first stage estimation is very strong. Table 4.2A, Panel A, column 1 shows that treatment allocation of households into water quality self-testing and information experiment leads to a participation rate of 71.2 percentage points (s.e. 1.7 percentage points). The result is robust to regression with baseline household and basic school controls (Panel A, column 2).

Surprisingly, we find that households offered the water quality testing and information was 2.5 percentage points less likely of reporting using soap or detergent during last time of handwashing (Panel A, column 3). The result is not robust to specifications including baseline household and basic school covariates (Panel A, column 4). In Panel A, column 5 we find that households offered the water quality testing and information was 5.8 percentage points more likely of having children wearing shoes/slippers based on enumerator's observation. The result is robust to specifications including baseline household and basic school characteristics (Panel A, column 6). Other than these results, we do not find evidence that household water quality testing and information had impacts on sanitation and hygiene practices. The results obtained using ITT estimation (Panel A) are similar to the IV estimation (Panel B).

Table 4.2A: Impacts on Sanitation and Hygiene Practices

	First stage		Sanitation and Hygiene Practices					
Dependent variable:	Participated		Last time respondent used soap/detergent to wash hands		Child is wearing shoes/slippers		Clothes of child are dirty/very dirty	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. ITT Estimation								
Treatment	0.712***	0.747***	-0.025*	-0.024	0.058**	0.079***	-0.009	-0.032
	(0.017)	(0.017)	(0.015)	(0.015)	(0.025)	(0.026)	(0.022)	(0.023)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1396	1364	1,392	1,360	1,370	1,339	1,366	1,335
R-squared	0.555	0.597	0.002	0.027	0.004	0.041	0.000	0.046
Mean (SD) of dependent variable in the comparison group	0	0	0.929	0.929	0.641	0.641	0.226	0.226
	(0)	(0)	(0.257)	(0.257)	(0.480)	(0.480)	(0.419)	(0.419)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"								
Participated			-0.036*	-0.032	0.082**	0.106***	-0.012	-0.042
			(0.021)	(0.020)	(0.035)	(0.034)	(0.031)	(0.031)
Household Controls			No	Yes	No	Yes	No	Yes
Basic School Controls			No	Yes	No	Yes	No	Yes
Observations			1,392	1,360	1,370	1,339	1,366	1,335
R-squared			-0.005	0.023	0.002	0.034	0.001	0.047
Mean (SD) dependent variable in the comparison group			0.929	0.929	0.641	0.641	0.226	0.226
			(0.257)	(0.257)	(0.480)	(0.480)	(0.419)	(0.419)

Table 4.2A: Impacts on Sanitation and Hygiene Practices (continued)

	Sanitation and Hygiene Practices							
Dependent variable:	Face and hands of child are dirty/very dirty		Surrounding of household is clean/average		Latrine or toilet is very clean/clean enough		Respondent mentioned at least three instances of handwashing yesterday	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Panel A. ITT Estimation								
Treatment	-0.007	-0.021	0.021	0.026	-0.018	0.007	0.012	0.023
	(0.020)	(0.021)	(0.021)	(0.022)	(0.041)	(0.042)	(0.023)	(0.022)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,363	1,332	1,401	1,368	376	366	1,401	1,368
R-squared	0.000	0.050	0.001	0.019	0.001	0.090	0.000	0.197
Mean (SD) of dependent variable in the comparison group	0.171	0.171	0.804	0.804	0.819	0.819	0.733	0.733
	(0.377)	(0.377)	(0.397)	(0.397)	(0.386)	(0.386)	(0.442)	(0.442)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"								
Participated	-0.009	-0.029	0.030	0.034	-0.028	0.010	0.017	0.030
	(0.028)	(0.027)	(0.029)	(0.030)	(0.062)	(0.060)	(0.033)	(0.029)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,363	1,332	1,401	1,368	376	366	1,401	1,368
R-squared	0.001	0.049	-0.001	0.016	-0.001	0.090	0.001	0.196
Mean (SD) dependent variable in the comparison group	0.171	0.171	0.804	0.804	0.819	0.819	0.733	0.733
	(0.377)	(0.377)	(0.397)	(0.397)	(0.386)	(0.386)	(0.442)	(0.442)

Notes: Robust standard errors in parentheses. Household and household head baseline controls include: household head is a male, head's age, head is married, head belongs to Ga/Adangbe ethnic group, head is a Christian, household is located in urban district (Ga South Municipal), household expenditure is high (i.e. 1 if the household is in percentiles 50-100 of annual expenditure), household undertakes irrigated agriculture, household has electricity, and number of female members under 15 years of age. Basic school controls include: school project contact person (i.e. SHEP coordinator) is a male.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Source: First, second and third follow-up round surveys in November/December 2014, January/February 2015, and May/June 2015.

4.4.1.B. Differential Impacts on Sanitation and Hygiene Practices

We now explore the heterogeneous treatment effects as a function of assignment into the study arms. Here we use both ITT (results in Table 4.2B Panel A) and IV (results in Table 4.2B, Panel B) estimation strategies. The first stage regression shows very strong relationship between treatment assignment and participation in the experiment. Treatment assignment leads to participation by households in the school children treatment group of 85.1 percentage points (s.e. 2.0 percentage points) while participation by households in the adult household members intervention group was 57.5 percentage points (s.e. 2.7 percentage points). Table 4.2B shows the differential impacts on sanitation and hygiene practices. Panel A, column (5) reports the impact on the child wearing shoes/slippers. A child wearing shoes/slippers is 6.8 percentage points higher for households in the school children intervention group (s.e. 3.1 percentage points, relative to the average value of 64.1 percent in the comparison group). The result is robust to regressions including baseline household and basic school covariates (Panel A, column 6). We find that children wearing shoes/slippers are 11 percentage points higher in the adult household members intervention group (significant at 99 percent, with regressions including baseline covariates but not significant without baseline covariates).

Panel A, column (8) shows that children in the households in the adult household members intervention group were 6.2 percentage points (significant at 90 percent in regressions with baseline household and basic school covariates, not significant in regressions without baseline household and basic school covariates) less likely to be wearing dirty/very dirty clothes (s.e. 3.4 percentage points, relative to average value of 22.6 percent in the comparison group). We find no statistically significant additional effect for children in the households in the school children intervention group. Panel A, column (11) reports that households in the adult household members intervention group were 5.9 percentage points more likely to have surroundings of their dwellings to be clean or average (s.e. 2.4 percentage points, relative to the average value of 80.4 percent in the comparison group). The result is robust to regression specifications including baseline household and basic school covariates (Panel A, column 12).

Panel A, column (14) reports the impacts on the cleanliness of latrine/toilet. Households in the adult household members intervention are 12.8 percentage points (significant at 95 percent in regressions with baseline household and basic school covariates, but not significant in specifications without the baseline household and basic school controls) more likely to have toilet/latrine observed to be very clean or clean enough (s.e. 6 percentage points, relative to average value of 81.9 percent in the comparison group). There is no statistically significant effect for households in the school children intervention groups. Similarly, results in Panel A, column 16 shows that households in the adult household members intervention group are 6 percentage points (significant at 90 percent in regressions with baseline household and basic school covariates, but not significant in specifications without the baseline household and basic school controls) more likely to mention at least three instances of handwashing the previous day preceding the surveys (s.e. 3.3 percentage points, relative to average value of 73.3 percent in the comparison group). There is no statistically significant effect for households in the school children intervention groups. The results obtained using the ITT estimation is similar to those obtained from the IV estimation.

Table 4.2B: Differential Impacts on Sanitation and Hygiene Practices

	First stage		Sanitation and Hygiene Practices					
Dependent variable:	Child Participated	Adult participated	Last time respondent used soap/detergent to wash hands		Child is wearing shoes/slippers		Clothes of child are dirty/very dirty	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. ITT Estimation								
Child treatment	0.851***	0.007	-0.020	-0.013	0.068**	0.056*	-0.024	-0.009
	(0.020)	(0.005)	(0.018)	(0.019)	(0.031)	(0.032)	(0.027)	(0.028)
Adult treatment	0.031	0.575***	-0.030	-0.037	0.049	0.110***	0.007	-0.062*
	(0.008)	(0.027)	(0.019)	(0.023)	(0.031)	(0.037)	(0.028)	(0.034)
Household Controls	Yes	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	Yes	Yes	No	Yes	No	Yes	No	Yes
Observations	1360	1360	1,392	1,360	1,370	1,339	1,366	1,335
R-squared	0.831	0.519	0.002	0.028	0.004	0.042	0.001	0.047
Mean (SD) of dependent variable in the comparison group	0 (0)	0 (0)	0.929 (0.257)	0.929 (0.257)	0.641 (0.480)	0.641 (0.480)	0.226 (0.419)	0.226 (0.419)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"								
Child participated			-0.024	-0.015	0.080**	0.064*	-0.028	-0.009
			(0.022)	(0.022)	(0.036)	(0.037)	(0.032)	(0.032)
Adult participated			-0.052	-0.064	0.085	0.187***	0.012	-0.107*
			(0.033)	(0.040)	(0.054)	(0.064)	(0.048)	(0.058)
Household Controls			No	Yes	No	Yes	No	Yes
Basic School Controls			No	Yes	No	Yes	No	Yes
Observations			1,392	1,360	1,370	1,339	1,366	1,335
R-squared			-0.006	0.019	0.002	0.034	0.000	0.050
Mean (SD) dependent variable in the comparison group			0.929 (0.257)	0.929 (0.257)	0.641 (0.480)	0.641 (0.480)	0.226 (0.419)	0.226 (0.419)

Table 4.2B: Differential Impacts on Sanitation and Hygiene Practices (continued)

	Sanitation and Hygiene Practices							
Dependent variable:	Face and hands of child are dirty/very dirty		Surrounding of household is clean/average		Latrine or toilet is very clean/clean enough		Respondent mentioned at least three instances of handwashing yesterday	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Panel A. ITT Estimation								
Child treatment	-0.013	0.001	-0.017	-0.042	-0.064	-0.058	0.009	-0.007
	(0.025)	(0.025)	(0.027)	(0.028)	(0.048)	(0.051)	(0.029)	(0.028)
Adult treatment	-0.000	-0.050	0.059**	0.113***	0.053	0.128**	0.015	0.060*
	(0.025)	(0.031)	(0.024)	(0.031)	(0.048)	(0.060)	(0.029)	(0.033)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,363	1,332	1,401	1,368	376	366	1,401	1,368
R-squared	0.000	0.051	0.005	0.031	0.013	0.110	0.000	0.199
Mean (SD) of dependent variable in the comparison group	0.171	0.171	0.804	0.804	0.819	0.819	0.733	0.733
	(0.377)	(0.377)	(0.397)	(0.397)	(0.386)	(0.386)	(0.442)	(0.442)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"								
Child participated	-0.015	0.002	-0.020	-0.051	-0.078	-0.067	0.011	-0.009
	(0.029)	(0.029)	(0.031)	(0.033)	(0.059)	(0.061)	(0.034)	(0.033)
Adult participated	-0.000	-0.087	0.103**	0.199***	0.126	0.330**	0.026	0.106*
	(0.043)	(0.053)	(0.042)	(0.054)	(0.112)	(0.146)	(0.050)	(0.057)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,363	1,332	1,401	1,368	376	366	1,401	1,368
R-squared	0.001	0.050	0.001	0.015	0.013	0.094	0.001	0.199
Mean (SD) dependent variable in the comparison group	0.171	0.171	0.804	0.804	0.819	0.819	0.733	0.733
	(0.377)	(0.377)	(0.397)	(0.397)	(0.386)	(0.386)	(0.442)	(0.442)

Note: Refer to Table 4.2A

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

4.4.2.A. Impacts on Diarrhea Prevention Knowledge

Table 4.3A presents the results on the impacts on diarrhea prevention knowledge. We find generally mixed results. Specifically, Panel A, column (1) shows 43.1 percent of the households in the comparison group names hand-washing as the best way to prevent diarrhea. This proportion is decreased by 6 percentage points (s.e. 2.6 percentage points) among those households in the treatment arm. The result is robust to specifications including baseline household controls (Panel A, column 2). Recall that the baseline summary statistics of these indicators were not balanced. In addressing these imbalances at the baseline level, we run separate regressions which include the baseline covariate of each dependent variable as part of the household controls and the results are presented in Panel A, columns (3) and (6). We find that the results do not change, except that the insignificant results for respondent naming use of clean drinking water as the best way of preventing diarrhea rather becomes significant. Furthermore, including baseline covariates of the outcome variables as part of the controls actually increases the magnitude of the coefficient. Lastly, we find that results obtained using the ITT estimation (Panel A) are similar to those obtained using the IV estimation (Panel B) in terms of sign and statistical significance.

Table 4.3A: Impacts on Diarrhea Prevention Knowledge

	Diarrhea Prevention Knowledge					
Dependent variable:	Respondent names hand-washing as the best way to prevent diarrhea			Respondent names use of clean drinking water as the best way to prevent diarrhea		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. ITT Estimation						
Treatment	-0.060**	-0.065**	-0.078***	0.030	0.028	0.042*
	(0.026)	(0.027)	(0.027)	(0.023)	(0.024)	(0.025)
Household Controls	No	Yes	Yes	No	Yes	Yes
Basic School Controls	No	Yes	Yes	No	Yes	Yes
Inclusion of baseline covariate of the dependent variable	No	No	Yes	No	No	Yes
Observations	1,382	1,349	1,269	1,382	1,349	1,269
R-squared	0.004	0.070	0.071	0.001	0.026	0.032
Mean (SD) of dependent variable in the comparison group	0.431 (0.496)	0.431 (0.496)	0.431 (0.496)	0.220 (0.415)	0.220 (0.415)	0.220 (0.415)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"						
Participated	-0.085**	-0.088**	-0.104***	0.042	0.037	0.055*
	(0.037)	(0.036)	(0.037)	(0.032)	(0.032)	(0.033)
Household Controls	No	Yes	Yes	No	Yes	Yes
Basic School Controls	No	Yes	Yes	No	Yes	Yes
Inclusion of baseline covariate of the dependent variable	No	No	Yes	No	No	Yes
Observations	1,382	1,349	1,269	1,382	1,349	1,269
R-squared	0.000	0.067	0.065	-0.001	0.023	0.028
Mean (SD) dependent variable in the comparison group	0.431 (0.496)	0.431 (0.496)	0.431 (0.496)	0.220 (0.415)	0.220 (0.415)	0.220 (0.415)

Notes: Refer to Table 4.2A. Additional controls include baseline covariates of each of the dependent variable to cater for imbalances in the baseline summary statistics.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

4.4.2.B. Differential Impacts on Diarrhea Prevention Knowledge

Table 4.3B presents the differential impacts of the treatment arms on diarrhea prevention knowledge of the households. We find an important shift in the knowledge of respondents in terms of best ways to prevent diarrhea. Specifically, Panel A, column (1) shows that households in the school children intervention group are 8.3 percentage points less likely of naming hand-washing as the best way to prevent diarrhea (s.e. 3.9 percentage points, relative to the average value of 43.1 percent in the comparison group). By introducing baseline covariate of the handwashing variable (Panel A, column 3), we find that the result is still robust. However, the estimate for households in the adult household members intervention group becomes significant only after introducing the baseline household and basic school covariates and also that of the baseline hand washing variable (Panel A, columns (2) and (3)).

In Panel A, column 6 we find that households in the adult household members intervention group are 7.1 percentage points (significant at 95 percent, with baseline covariates but not significant without baseline covariates) more likely to name using clean drinking water as the best way to prevent diarrhea (s.e. 3.6 percentage points, relative to average value of 22 percent in the comparison group). There is no statistically significant additional effect for households in the school children intervention group. Finally, results obtained using ITT estimation (Panel A) and IV estimation (Panel B) are similar.

Table 4.3B: Differential Impacts on Diarrhea Prevention Knowledge

	Diarrhea Prevention Knowledge					
Dependent variable:	Respondent names hand-washing as the best way to prevent diarrhea			Respondent names use of clean drinking water as the best way to prevent diarrhea		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. ITT Estimation						
Child treatment	-0.083***	-0.059*	-0.058*	0.035	0.010	0.019
	(0.032)	(0.033)	(0.035)	(0.028)	(0.029)	(0.031)
Adult treatment	-0.038	-0.074**	-0.104***	0.025	0.052	0.071**
	(0.032)	(0.037)	(0.039)	(0.028)	(0.034)	(0.036)
Household Controls	No	Yes	Yes	No	Yes	Yes
Basic School Controls	No	Yes	Yes	No	Yes	Yes
Inclusion of baseline covariate of the depen. variable	No	No	Yes	No	No	Yes
Observations	1,382	1,349	1,269	1,382	1,349	1,269
R-squared	0.005	0.070	0.071	0.001	0.027	0.034
Mean (SD) of dependent variable in the comparison group	0.431 (0.496)	0.431 (0.496)	0.431 (0.496)	0.220 (0.415)	0.220 (0.415)	0.220 (0.415)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"						
Child participated	-0.098***	-0.068*	-0.068	0.041	0.011	0.021
	(0.038)	(0.039)	(0.042)	(0.033)	(0.034)	(0.036)
Adult participated	-0.065	-0.125*	-0.171***	0.044	0.089	0.119**
	(0.056)	(0.065)	(0.065)	(0.049)	(0.059)	(0.060)
Household Controls	No	Yes	Yes	No	Yes	Yes
Basic School Controls	No	Yes	Yes	No	Yes	Yes
Inclusion of baseline covariate of the dependent variable	No	No	Yes	No	No	Yes
Observations	1,382	1,349	1,269	1,382	1,349	1,269
R-squared	0.002	0.065	0.061	-0.001	0.019	0.023
Mean (SD) dependent variable in the comparison group	0.431 (0.496)	0.431 (0.496)	0.431 (0.496)	0.220 (0.415)	0.220 (0.415)	0.220 (0.415)

Note: Refer to Table 4.2A

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

4.4.3.A. Impacts on Overall Well-being and Health

Tables 4.4A and 4.5A present the impacts on overall well-being and health. Table 4.4A relies on responses from individual household members while Table 4.5A relies on household level data. Table 4.5A explores the three time frames for the definition of diarrhea and malaria (such as cases in the past one week, past two weeks and past one month). The time frames of past one week and past two weeks are used as robustness checks for the preferred time frame of past one month. Diarrhea is based on self-report of any household member who had three or more liquid stools in the past 24 hours; the standard WHO definition. Malaria is defined based on self-report by respondents of any household member suffering from fever or any other malarial symptom during any of the time frames. Household water quality testing and information do not have statistically significant effects on overall well-being and health of householders (Tables 4.4A and 4.5A). In some cases, the effect is rather negative. For instance, using the simplest regression specification based on the experimental design, household members reporting of any illness or injury in the past four weeks preceding the surveys increased by 3.6 percentage points (s.e. 0.8 percentage points, Table 4.4A, Panel A, column 1). The estimated result is robust to specifications including baseline household and basic school covariates (Table 4.4A, Panel A, column 2). What accounted for this potential increase apart from other possible reasons could be due to increase in knowledge and awareness of households on health issues leading to a high report of health problems.

In Table 4.5A, Panel A, we do not find any statistically significant additional effect on diarrhea and malaria cases. Other than the result of illness and injury in the past four weeks preceding the surveys, we do not find any evidence that household water quality testing and information leads to improvement in overall well-being and health. As additional robustness checks, we run separate regressions including baseline covariates of malaria and diarrhea indicators as part of the baseline household and basic school controls. We also include other covariates apart from the standard controls used in the previous Tables such as the household use of improved water and sanitation, and in the case of diarrhea, we include diarrhea prevention knowledge and respondents indicating the use of clean water as the best way of preventing diarrhea. In the case of malaria, we also include the household use of bed nets (the results are presented in Appendix Table A2). We still find that there is no statistically significant effect on reduction of diarrhea and malaria cases in the treatment group compared to the control group. As usual, the results from the IV estimation (Panel B) are similar to that of ITT estimation (Panel A).

Table 4.4A: Impacts on Overall Well-being and Health

Dependent variable:	Overall Well-being and Health			
	Household member reported any illness or injury in the past 4 weeks		Overall, the respondent rates health of household members as very healthy/somewhat healthy	
	(1)	(2)	(3)	(4)
Panel A. ITT Estimation				
Treatment	0.036***	0.030***	-0.005	-0.002
	(0.008)	(0.009)	(0.004)	(0.004)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	8,954	8,226	8,505	8,248
R-squared	0.002	0.187	0.000	0.013
Mean (SD) of dependent variable in the comparison group	0.176 (0.381)	0.176 (0.381)	0.962 (0.191)	0.962 (0.191)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"				
Participated	0.052***	0.040***	-0.007	-0.003
	(0.012)	(0.012)	(0.006)	(0.006)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	8,947	8,685	8,498	8,241
R-squared	0.003	0.017	-0.000	0.013
Mean (SD) dependent variable in the comparison group	0.176 (0.381)	0.176 (0.381)	0.962 (0.191)	0.962 (0.191)

Table 4.5A: Impacts on Diarrhea and Malaria Cases

	Diarrhea and malaria cases					
Dependent variable:	Household reported at least one diarrhea episode in the past one week		Household reported at least one diarrhea episode in the past two weeks		Household reported at least one diarrhea episode in the past one month	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. ITT Estimation						
Treatment	0.012	0.009	0.011	0.006	0.027	0.019
	(0.013)	(0.014)	(0.016)	(0.017)	(0.019)	(0.020)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,401	1,373	1,401	1,373	1,401	1,373
R-squared	0.001	0.012	0.000	0.016	0.001	0.012
Mean (SD) of dependent variable in the comparison group	0.061	0.061	0.094	0.094	0.140	0.140
	(0.239)	(0.239)	(0.293)	(0.293)	(0.347)	(0.347)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"						
Participated	0.016	0.013	0.015	0.008	0.037	0.025
	(0.019)	(0.019)	(0.022)	(0.023)	(0.027)	(0.027)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,401	1,373	1,401	1,373	1,401	1,373
R-squared	0.002	0.013	0.001	0.016	0.003	0.014
Mean (SD) dependent variable in the comparison group	0.061	0.061	0.094	0.094	0.140	0.140
	(0.239)	(0.239)	(0.293)	(0.293)	(0.347)	(0.347)

Table 4.5A: Impacts on Diarrhea and Malaria Cases (continued)

	Diarrhea and malaria cases					
Dependent variable:	Household reported at least one malaria case in the past one week		Household reported at least one malaria case in the past two weeks		Household reported at least one malaria case in the past one month	
	(7)	(8)	(9)	(10)	(11)	(12)
Panel A. ITT Estimation						
Treatment	-0.009	-0.015	-0.010	-0.021	-0.014	-0.032
	(0.019)	(0.019)	(0.023)	(0.023)	(0.026)	(0.027)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,401	1,373	1,401	1,373	1,401	1,373
R-squared	0.000	0.013	0.000	0.019	0.000	0.021
Mean (SD) of dependent variable in the comparison group	0.144	0.144	0.236	0.236	0.382	0.382
	(0.351)	(0.351)	(0.425)	(0.425)	(0.486)	(0.486)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"						
Participated	-0.013	-0.020	-0.014	-0.029	-0.019	-0.043
	(0.026)	(0.026)	(0.032)	(0.031)	(0.036)	(0.036)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,401	1,373	1,401	1,373	1,401	1,373
R-squared	0.001	0.013	0.001	0.019	0.001	0.021
Mean (SD) dependent variable in the comparison group	0.144	0.144	0.236	0.236	0.382	0.382
	(0.351)	(0.351)	(0.425)	(0.425)	(0.486)	(0.486)

Note: Refer to Table 4.2A
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

4.4.3.B. Differential Impacts on Overall Well-being and Health

Interestingly, while we largely do not find statistically significant impacts on overall well-being and health under section 4.4.3.A, we find differential impacts based on the different treatment arms. In Table 4.4B, Panel A, column 1, we find that household members reporting of suffering from any illness or injury in the past four weeks preceding the surveys for those in the school children and adult household members intervention groups increase by 4.4 and 2.8 percentage points, respectively (relative to average value of 17.6 percent in the comparison group). The result for household members in the school children group is robust to regression specifications including baseline household and basic school covariates (Panel 4, column 2). Panel A, column 3 presents the differential impacts on respondent's rating of the health of household members as very healthy or somewhat healthy. Very healthy or somewhat healthy household members are 1.3 percentage points lower in the adult household members intervention group (s.e. 0.6 percentage points, relative to the average value of 96.2 percent in the comparison group). There is no statistically significant additional effect for household members in the school children intervention group.

We do not largely find statistically significant effect in terms of reduction in diarrhea and malaria cases (Table 4.5B, Panel A), except in Panel A, column 12 where malaria cases in the past one month reduced by 6.7 percentage points in households in the adult household members intervention group (significant at 90 percent, with baseline covariates but not significant without baseline covariates). In Appendix Table A3, we explore the differential effects as functions of additional baseline covariates to the standard baseline household controls, including for instance household use of improved water and sanitation, and also baseline covariates of each dependent variable. Specifically, for the diarrhea analysis, we include also the diarrhea prevention knowledge and use of clean water as the best means of preventing diarrhea. For the analysis of malaria cases, we include the household use of bed nets as an additional control. We find that there is no statistically significant effect of the household water quality testing and information intervention on diarrhea and malaria reduction, even as we control for these additional covariates. The results obtained from the ITT estimation (Panel A) are similar to that of IV estimation (Panel B).

Table 4.4B: Differential Impacts on Overall Well-being and Health

Dependent variable:	Overall Well-being and Health			
	Household member reported any illness or injury in the past 4 weeks		Overall, the respondents rate health of household member as very healthy/somewhat healthy	
	(1)	(2)	(3)	(4)
Panel A. ITT Estimation				
Child treatment	0.044***	0.047***	0.003	0.005
	(0.010)	(0.011)	(0.005)	(0.005)
Adult treatment	0.028***	0.007	-0.013**	-0.012*
	(0.010)	(0.013)	(0.006)	(0.007)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	8,954	8,692	8,505	8,248
R-squared	0.002	0.016	0.001	0.013
Mean (SD) of dependent variable in the comparison group	0.176	0.176	0.962	0.962
	(0.381)	(0.381)	(0.191)	(0.191)
Panel B. Instrumental variable estimation: “child participated” and “adult participated” instrumented with “child treatment” and “adult treatment”				
Child participated	0.053***	0.055***	0.003	0.006
	(0.012)	(0.013)	(0.006)	(0.006)
Adult participated	0.051***	0.011	-0.022**	-0.021*
	(0.019)	(0.023)	(0.010)	(0.012)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	8,954	8,692	8,505	8,248
R-squared	0.003	0.017	0.001	0.014
Mean (SD) dependent variable in the comparison group	0.176	0.176	0.962	0.962
	(0.381)	(0.381)	(0.191)	(0.191)

Note: Refer to Table 4.2A

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table 4.5B: Differential Impacts on Diarrhea and Malaria Cases

	Diarrhea and Malaria Cases					
Dependent variable:	Household reported at least one diarrhea episode in the past one week		Household reported at least one diarrhea episode in the past two weeks		Household reported at least one diarrhea episode in the past one month	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. ITT Estimation						
Child treatment	0.007	0.003	0.011	0.014	0.027	0.028
	(0.016)	(0.018)	(0.020)	(0.021)	(0.024)	(0.026)
Adult treatment	0.016	0.018	0.011	-0.004	0.026	0.006
	(0.017)	(0.019)	(0.020)	(0.023)	(0.024)	(0.028)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,401	1,373	1,401	1,373	1,401	1,373
R-squared	0.001	0.012	0.000	0.016	0.001	0.013
Mean (SD) of dependent variable in the comparison group	0.061 (0.239)	0.061 (0.239)	0.094 (0.293)	0.094 (0.293)	0.140 (0.347)	0.140 (0.347)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"						
Child participated	0.008	0.003	0.013	0.016	0.032	0.033
	(0.019)	(0.021)	(0.023)	(0.025)	(0.028)	(0.030)
Adult participated	0.029	0.031	0.020	-0.007	0.045	0.009
	(0.029)	(0.033)	(0.034)	(0.041)	(0.041)	(0.049)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,401	1,373	1,401	1,373	1,401	1,373
R-squared	0.003	0.015	0.002	0.015	0.004	0.013
Mean (SD) dependent variable in the comparison group	0.061 (0.239)	0.061 (0.239)	0.094 (0.293)	0.094 (0.293)	0.140 (0.347)	0.140 (0.347)

Table 4.5B: Differential Impacts on Diarrhea and Malaria Cases (continued)

	Diarrhea and Malaria Cases					
Dependent variable:	Household reported at least one malaria case in the past one week		Household reported at least one malaria case in the past two weeks		Household reported at least one malaria case in the past one month	
	(7)	(8)	(9)	(10)	(11)	(12)
Panel A. ITT Estimation						
Child treatment	-0.009	-0.022	-0.005	-0.016	0.010	-0.004
	(0.023)	(0.024)	(0.028)	(0.030)	(0.032)	(0.034)
Adult treatment	-0.010	-0.007	-0.016	-0.028	-0.037	-0.067*
	(0.023)	(0.028)	(0.027)	(0.033)	(0.031)	(0.037)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,401	1,373	1,401	1,373	1,401	1,373
R-squared	0.000	0.013	0.000	0.019	0.001	0.022
Mean (SD) of dependent variable in the comparison group	0.144	0.144	0.236	0.236	0.382	0.382
	(0.351)	(0.351)	(0.425)	(0.425)	(0.486)	(0.486)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"						
Child participated	-0.011	-0.025	-0.005	-0.018	0.011	-0.003
	(0.027)	(0.028)	(0.033)	(0.034)	(0.038)	(0.040)
Adult participated	-0.017	-0.011	-0.027	-0.049	-0.064	-0.119*
	(0.039)	(0.049)	(0.047)	(0.059)	(0.055)	(0.066)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	1,401	1,373	1,401	1,373	1,401	1,373
R-squared	0.000	0.013	0.001	0.019	0.000	0.019
Mean (SD) dependent variable in the comparison group	0.144	0.144	0.236	0.236	0.382	0.382
	(0.351)	(0.351)	(0.425)	(0.425)	(0.486)	(0.486)

Note: Refer to Table 4.2A
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

4.4.4.A. Impacts on Child Health and Nutrition

Table 4.6A present comparison of health and nutrition indicators for children between the ages of 6 to 60 months enumerated in all the four survey waves. The results show that there was a limited improvement of anthropometric outcomes between wave one (baseline survey) and wave four (endline survey) across the treatment groups. Diarrhea incidence decrease for children in school children intervention group and also for those in the comparison group. In the adult household members intervention group, there are was an increase of diarrhea incidence, which was not statistically significant at the traditional confidence levels. Overall, the results show that there is no impact of water quality testing and information on child health and nutrition outcomes for children between the ages of 6 to 60 months enumerated in all the four survey waves. This is consistent with the results in Tables 4.6B and 4.6C where the water quality testing and information had no positive impacts on health and nutritional indicators of children between 0 to 8 years of age.

Table 4.6A: Summary Statistics of Health and Nutrition Indicators for Children between 6 to 60 Months in all Four Survey Waves

Variable	Description	Wave I	Wave II	Wave III	Wave IV	Test of significance between Wave I and IV
		Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (*p*-value)
Child treatment						
CHILD_HAZ	Height-for-age *z*-score	-1.153	-1.138	-1.244	-1.645	-0.367
		(1.817)	(1.416)	(1.275)	(1.202)	(0.330)
CHILD_WAZ	Weight-for-age *z*-score	-0.761	-0.756	-0.838	-1.061	-0.190
		(1.245)	(1.028)	(1.227)	(0.980)	(0.516)
CHILD_DIARR1MNTH	Child had diarrhea in the past 4 weeks	0.071	0.081	0.154	0.000	-0.074**
		(0.261)	(0.277)	(0.366)	(0.000)	(0.043)
Adult treatment						
CHILD_HAZ	Height-for-age *z*-score	-1.279	-0.992	-0.969	-1.059	0.220
		(1.119)	(1.164)	(1.323)	(1.607)	(0.580)
CHILD_WAZ	Weight-for-age *z*-score	-0.910	-0.703	-0.762	-0.718	0.192
		(1.144)	(1.003)	(1.208)	(1.384)	(0.592)
CHILD_DIARR1MNTH	Child had diarrhea in the past 4 weeks	0.028	0.194	0.148	0.095	0.048
		(0.167)	(0.402)	(0.362)	(0.301)	(0.381)
Comparison group						
CHILD_HAZ	Height-for-age *z*-score	-1.337	-1.393	-1.068	-1.439	-0.036
		(1.088)	(1.141)	(1.343)	(1.239)	(0.891)
CHILD_WAZ	Weight-for-age *z*-score	-0.954	-1.063	-0.857	-0.765	0.098
		(0.821)	(1.144)	(0.941)	(0.748)	(0.581)
CHILD_DIARR1MNTH	Child had diarrhea in the past 4 weeks	0.053	0.098	0.148	0.000	-0.078**
		(0.225)	(0.300)	(0.358)	(0.000)	(0.013)

Robust standard errors are estimated for the test of statistical significance for each of the outcome variables across waves one and four (results in column 7).

We estimate the impacts of the household water quality testing and information intervention on child health and nutrition (anthropometrics) and the results are presented in Table 4.6B. We expand the standard household baseline controls to include child specific variables such gender of the child, and age of the child in some of the regressions. We find no effect of household participation in the intervention on the main indicator of health, reduction in diarrheal incidence in the past four weeks (Panel A, column 1). Similarly, there is no effect on the main nutrition indicator, weight-for-height *z*-score (Panel A, column 9). We expand the analysis on child health and nutrition to include other variables apart from the main nutrition and health indicators such as malaria cases in the past four weeks, child height-for-age *z*-score, child weight-for-age *z*-score, among others. We largely find the same trend of no statistically significant additional effect, except surprising results which show decreases in height-for-age and weight-for-age *z*-scores (Panel A, columns (6) and (8) i.e. regressions including baseline household and basic school controls). We explore an IV estimation of all the variables (Panel B) and we find that the results are similar to the ITT estimation (Panel A).

Table 4.6B: Impacts on Child Health and Nutrition

	Child Health and Nutrition							
Dependent variable:	Child had diarrhea in the past 4 weeks indicator		Child had malaria in the past 4 weeks indicator		Height-for-age z-score		Weight-for-age z-score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. ITT Estimation								
Treatment	0.014	0.012	0.005	0.015	-0.098	-0.271***	-0.064	-0.158**
	(0.013)	(0.014)	(0.020)	(0.021)	(0.081)	(0.087)	(0.073)	(0.080)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Child gender-age controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,307	1,241	1,307	1,241	959	916	955	912
R-squared	0.001	0.025	0.000	0.036	0.002	0.072	0.001	0.036
Mean (SD) of dependent variable in the comparison group	0.052 (0.222)	0.052 (0.222)	0.151 (0.358)	0.151 (0.358)	-0.910 (1.260)	-0.910 (1.260)	-0.769 (1.083)	-0.769 (1.083)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"								
Participated	0.021	0.017	0.010	0.022	-0.136	-0.334***	-0.094	-0.204**
	(0.019)	(0.018)	(0.029)	(0.029)	(0.114)	(0.110)	(0.103)	(0.102)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Child gender-age controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,297	1,237	1,297	1,237	954	913	950	909
R-squared	0.001	0.026	0.000	0.037	0.008	0.073	0.007	0.045
Mean (SD) dependent variable in the comparison group	0.052 (0.222)	0.052 (0.222)	0.151 (0.358)	0.151 (0.358)	-0.910 (1.260)	-0.910 (1.260)	-0.769 (1.083)	-0.769 (1.083)

Table 4.6B: Impacts on Child Health and Nutrition (continued)

Dependent variable:	Child Health and Nutrition					
	Weight-for-height z-score		Body-mass-index-for-age z-score		Overall, the respondent rates health of child as very healthy/somewhat healthy	
	(9)	(10)	(11)	(12)	(13)	(14)
Panel A. ITT Estimation						
Treatment	0.034	0.062	0.047	0.076	-0.005	-0.001
	(0.090)	(0.099)	(0.087)	(0.095)	(0.011)	(0.012)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Child gender-age controls	No	Yes	No	Yes	No	Yes
Observations	826	787	943	900	1,266	1,207
R-squared	0.000	0.025	0.000	0.044	0.000	0.020
Mean (SD) of dependent variable in the comparison group	-0.413	-0.413	-0.326	-0.326	0.964	0.964
	(1.273)	(1.273)	(1.307)	(1.307)	(0.185)	(0.185)
Panel B. Instrumental variable estimation: “participated” instrumented with “treatment”						
Participated	0.038	0.064	0.059	0.084	-0.007	-0.002
	(0.130)	(0.125)	(0.123)	(0.121)	(0.015)	(0.016)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Child gender-age controls	No	Yes	No	Yes	No	Yes
Observations	821	784	938	897	1,266	1,207
R-squared	-0.002	0.022	-0.002	0.042	-0.001	0.020
Mean (SD) dependent variable in the comparison group	-0.413	-0.413	-0.326	-0.326	0.964	0.964
	(1.273)	(1.273)	(1.307)	(1.307)	(0.185)	(0.185)

Notes: Robust standard errors in parentheses. Household and household head baseline controls include: household head is a male, head’s age, head is married, head belongs to Ga/Adangbe ethnic group, head is a Christian, household is located in urban district (Ga South Municipal), household expenditure is high (i.e. 1 if the household is in percentiles 50-100 of annual expenditure), household undertakes irrigated agriculture, household has electricity, and number of female members under 15 years of age. Additional controls include household use improved water and sanitation. The child gender-age controls include gender of child, linear and square of the age in years. Basic school controls include: school project contact person (i.e. SHEP coordinator) is a male.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

4.4.4.B. Differential Impacts on Child Health and Nutrition

In Table 4.6C, we explore the heterogeneous impacts of the household water quality testing and information intervention on child health and nutrition as a function of the random assignment into the treatment arms. Panel A, column (4) presents the impacts on the incidence of malaria fever in the past four weeks preceding the surveys for children seven years old and below during the baseline survey or born after the baseline survey. Malaria fever is 4.9 percentage points higher for children eight years and below in the school children intervention group (relative to the average value of 15.1 percent for children in the comparison group). The result is not statistically significant in specifications without including both baseline children, household and basic school controls (Panel A, column (3)). We do not find any statistically significant effect for children in households of the adult intervention group.

In panel A, column (5), we find that children in the school children intervention group are 0.184 standard deviations lower in terms of height-for-age *z*-score (relative to the average value of -0.910standard deviations in the comparison group). The result is significant only in specifications without baseline covariates. In panel A, column (6) we find that children in the adult household members intervention group are 0.378 standard deviations lower in terms of height-for-age z-score compared with their counterparts in the comparison group. The result is significant only in specifications with baseline covariates. In panel A, column (8) the result shows that children in the school children intervention group are 0.168 standard deviations lower in terms of weight-for-age *z*-score (relative to the average value of -0.769 standard deviations in the comparison) than their counterparts in the comparison group. The result is not robust to regression specifications without including baseline child, household and basic school controls. The results for children in the adult household members intervention group are not statistically significant in any of the regression specifications (Panel A, columns (7) and (8)). These results are not so surprising since at baseline the control group had relatively older children compared to the treatment groups. Also, the duration of the follow-up surveys of about seven months after the intervention maybe too short a time to observe improvement in anthropometric outcomes. Lastly, the results obtained with the ITT estimation are similar to those obtained from the IV estimation.

Table 4.6C: Differential Impacts on Child Health and Nutrition

	Child Health and Nutrition							
Dependent variable:	Child had diarrhea in the past 4 weeks indicator		Child had malaria in the past 4 weeks indicator		Height-for-age z-score		Weight-for-age z-score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. ITT Estimation								
Child treatment	0.021	0.016	0.031	0.049*	-0.184*	-0.185	-0.121	-0.168*
	(0.017)	(0.019)	(0.025)	(0.028)	(0.099)	(0.114)	(0.090)	(0.099)
Adult treatment	0.006	0.007	-0.023	-0.028	-0.019	-0.378***	-0.011	-0.147
	(0.016)	(0.020)	(0.023)	(0.030)	(0.098)	(0.122)	(0.088)	(0.117)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Child gender-age controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,307	1,241	1,307	1,241	959	916	955	912
R-squared	0.001	0.025	0.003	0.040	0.004	0.074	0.002	0.036
Mean (SD) of dependent variable in the comparison group	0.052 (0.222)	0.052 (0.222)	0.151 (0.358)	0.151 (0.358)	-0.910 (1.260)	-0.910 (1.260)	-0.769 (1.083)	-0.769 (1.083)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"								
Child participated	0.026	0.017	0.037	0.056*	-0.214*	-0.190	-0.141	-0.177*
	(0.020)	(0.021)	(0.030)	(0.031)	(0.115)	(0.121)	(0.105)	(0.105)
Adult participated	0.011	0.014	-0.042	-0.051	-0.034	-0.665***	-0.020	-0.260
	(0.029)	(0.037)	(0.043)	(0.054)	(0.174)	(0.209)	(0.159)	(0.205)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Child gender-age controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1,307	1,241	1,307	1,241	959	916	955	912
R-squared	0.002	0.026	0.002	0.039	0.006	0.075	0.004	0.047
Mean (SD) dependent variable in the comparison group	0.052 (0.222)	0.052 (0.222)	0.151 (0.358)	0.151 (0.358)	-0.910 (1.260)	-0.910 (1.260)	-0.769 (1.083)	-0.769 (1.083)

Table 4.6C: Differential Impacts on Child Health and Nutrition (continued)

	Child Health and Nutrition					
Dependent variable:	Weight-for-height z-score		Body-mass-index-for-age z-score		Overall, the respondent rates health of child as very healthy/somewhat healthy	
	(9)	(10)	(11)	(12)	(13)	(14)
Panel A. ITT Estimation						
Child treatment	0.002	-0.072	0.070	0.006	-0.007	-0.014
	(0.112)	(0.121)	(0.109)	(0.117)	(0.013)	(0.016)
Adult treatment	0.060	0.224	0.027	0.160	-0.002	0.015
	(0.107)	(0.141)	(0.103)	(0.133)	(0.013)	(0.017)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Child gender-age controls	No	Yes	No	Yes	No	Yes
Observations	826	787	943	900	1,266	1,207
R-squared	0.000	0.028	0.000	0.045	0.000	0.022
Mean (SD) of dependent variable in the comparison group	-0.413	-0.413	-0.326	-0.326	0.964	0.964
	(1.273)	(1.273)	(1.307)	(1.307)	(0.185)	(0.185)
Panel B. Instrumental variable estimation: “child participated” and “adult participated” instrumented with “child treatment” and “adult treatment”						
Child participated	0.003	-0.082	0.082	0.004	-0.008	-0.016
	(0.134)	(0.130)	(0.128)	(0.124)	(0.016)	(0.018)
Adult participated	0.108	0.386	0.048	0.284	-0.004	0.027
	(0.192)	(0.242)	(0.183)	(0.235)	(0.024)	(0.031)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Child gender-age controls	No	Yes	No	Yes	No	Yes
Observations	826	787	943	900	1,266	1,207
R-squared	-0.006	0.001	-0.002	0.031	-0.002	0.016
Mean (SD) dependent variable in the comparison group	-0.413	-0.413	-0.326	-0.326	0.964	0.964
	(1.273)	(1.273)	(1.307)	(1.307)	(0.185)	(0.185)

Notes: Robust standard errors in parentheses. Household and household head baseline controls include: household head is a male, head’s age, head is married, head belongs to Ga/Adangbe ethnic group, head is a Christian, household is located in urban district (Ga South Municipal), household expenditure is high (i.e. 1 if the household is in percentiles 50-100 of annual expenditure), household undertakes irrigated agriculture, household has electricity, and number of female members under 15 years of age. Additional controls include household use improved water and sanitation. The child gender-age controls include gender of child, linear and square of the age in years. Basic school controls include: school project contact person (i.e. SHEP coordinator) is a male.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

4.4.5 Gendered Treatment Effects of Household Water Quality Testing and Information on Health Outcomes, and Sanitation and Hygiene Behaviors

We explore the gendered treatment effects of the household water quality testing and information experiment on health outcomes, and sanitation and hygiene practices. The results for the various sub-themes (Tables 4.7A-E) have been placed under a common sub-section for easy reference. The results show limited treatment effects based on the gender of participants. We largely find no statistically significant effects on most of the outcome variables.

In Table 4.7A, we find little evidence of gendered treatment effects of household water quality testing and information on sanitation and hygiene practices. Households with male participants are 6.5 percentage points (significant at 90 percent, with baseline covariates but not significant without baseline covariates) less likely of naming at least three instances of handwashing the previous day preceding the surveys (column 14). In Table 4.7B, we find limited evidence of gendered treatment effects on diarrhea prevention knowledge. Households with male participants are 10.9 percentage points less likely of naming hand-washing as the best way in preventing diarrhea (column 1). The result is robust to specifications including baseline household and basic school covariates (columns 2 and 3). In column (5), households with male participants are 7.4 percent (significant at 90 percent, with baseline household and basic school covariates) more likely of indicating that the use of clean drinking water is the best way of preventing diarrhea.

Table 4.7C presents the gendered treatment effects on overall well-being and health of household members. In column 1, households with male participants are 4.1 percentage points less likely to report any illness or injury in the past four weeks preceding the survey. The result is robust to specifications including baseline household and basic school controls (column 2). Table 4.7D shows the effects of the gender of participants on household diarrhea and malaria cases. We do not find statistically significant results of the impacts of the gender of the participants in the household water quality testing and information on diarrhea and malaria cases. In Appendix Table A4, we included additional baseline household controls such as baseline covariates of each dependent variable, household use of improved water and sanitation, and other diarrhea and malaria specific variables. We find evidence of no statistically significant effect on diarrhea and malaria reduction. In Table 4.7E, we do not find statistically significant impacts on child health and nutrition.

Table 4.7A: Gendered Treatment Effects on Sanitation and Hygiene Practices

	Sanitation and Hygiene Practices							
Dependent variable:	Last time respondent used soap/detergent to wash hands		Child is wearing shoes/slippers		Clothes of child are dirty/very dirty		Face and hands of child are dirty/very dirty	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Male participated	-0.009	0.003	0.003	-0.008	0.013	0.032	0.006	0.020
	(0.025)	(0.029)	(0.043)	(0.046)	(0.037)	(0.039)	(0.034)	(0.035)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	473	465	467	459	467	459	466	458
R-squared	0.000	0.029	0.000	0.034	0.000	0.025	0.000	0.049
Mean (SD) of dependent variable in the female participated group	0.925	0.925	0.701	0.701	0.189	0.189	0.150	0.150
	(0.263)	(0.263)	(0.459)	(0.459)	(0.392)	(0.392)	(0.357)	(0.357)

	Sanitation and Hygiene Practices					
Dependent variable:	Surrounding of household is clean/average		Latrine or toilet is very clean/clean enough		Respondent mentioned at least three instances of handwashing yesterday	
	(9)	(10)	(11)	(12)	(13)	(14)
Male participated	-0.008	-0.018	-0.064	-0.099	-0.038	-0.065*
	(0.036)	(0.037)	(0.068)	(0.065)	(0.039)	(0.039)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	476	468	143	139	476	468
R-squared	0.000	0.020	0.006	0.096	0.002	0.187
Mean (SD) of dependent variable in the female participated group	0.821	0.821	0.833	0.833	0.778	0.778
	(0.384)	(0.384)	(0.375)	(0.375)	(0.416)	(0.416)

Note: Refer to Table 4.2A
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 4.7B: Gendered Treatment Effects on Diarrhea Prevention Knowledge

	Diarrhea Prevention Knowledge					
Dependent variable:	Respondent names hand-washing as the best way to prevent diarrhea			Respondent names use of clean drinking water as the best way to prevent diarrhea		
	(1)	(2)	(3)	(4)	(5)	(6)
Male participated	-0.109**	-0.140***	-0.145***	0.054	0.074*	0.063
	(0.044)	(0.046)	(0.047)	(0.040)	(0.044)	(0.045)
Household Controls	No	Yes	Yes	No	Yes	Yes
Basic School Controls	No	Yes	Yes	No	Yes	Yes
Inclusion of baseline covariate of the dependent variable	No	No	Yes	No	No	Yes
Observations	469	461	428	469	461	428
R-squared	0.013	0.098	0.096	0.004	0.039	0.043
Mean (SD) of dependent variable in the female participated group	0.425 (0.495)	0.425 (0.495)	0.425 (0.495)	0.220 (0.415)	0.220 (0.415)	0.220 (0.415)

Note: Refer to Table 4.2A
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 4.7C: Gendered Treatment Effects on Overall Well-being and Health

	Overall Well-being and Health			
Dependent variable:	Household member reported any illness or injury in the past 4 weeks		Overall, the respondents rate health of household member as very healthy/somewhat healthy	
	(1)	(2)	(3)	(4)
Male participated	-0.041***	-0.030*	0.005	-0.004
	(0.015)	(0.016)	(0.007)	(0.008)
Household Controls	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes
Observations	3,008	2,952	2,892	2,836
R-squared	0.002	0.029	0.000	0.019
Mean (SD) of dependent variable in the female participated group	0.241 (0.428)	0.241 (0.428)	0.956 (0.205)	0.956 (0.205)

Note: Refer to Table 4.2A
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 4.7D: Gendered Treatment Effects on Diarrhea and Malaria Cases

	Diarrhea and Malaria Cases					
Dependent variable:	Household reported at least one diarrhea episode in the past one week		Household reported at least one diarrhea episode in the past two weeks		Household reported at least one diarrhea episode in the past one month	
	(1)	(2)	(3)	(4)	(5)	(6)
Male participated	-0.021	-0.032	-0.028	-0.038	-0.030	-0.037
	(0.025)	(0.028)	(0.029)	(0.032)	(0.035)	(0.038)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	476	468	476	468	476	468
R-squared	0.001	0.026	0.002	0.026	0.002	0.041
Mean (SD) of dependent variable in the female participated group	0.089	0.089	0.128	0.128	0.195	0.195
	(0.286)	(0.286)	(0.335)	(0.335)	(0.397)	(0.397)

Table 4.7D: Gendered Treatment Effects on Diarrhea and Malaria Cases (continued)

	Diarrhea and Malaria Cases					
Dependent variable:	Household reported at least one malaria case in the past one week		Household reported at least one malaria case in the past two weeks		Household reported at least one malaria case in the past one month	
	(7)	(8)	(9)	(10)	(11)	(12)
Male participated	-0.017	-0.029	-0.029	-0.047	0.011	0.020
	(0.031)	(0.035)	(0.038)	(0.042)	(0.044)	(0.048)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Observations	476	468	476	468	476	468
R-squared	0.001	0.016	0.001	0.019	0.000	0.020
Mean (SD) of dependent variable in the female participated group	0.136	0.136	0.230	0.230	0.354	0.354
	(0.344)	(0.344)	(0.421)	(0.421)	(0.479)	(0.479)

Note: Refer to Table 4.2A
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 4.7E: Gendered Treatment Effects on Child Health and Nutrition

	Child Health and Nutrition							
Dependent variable:	Child had diarrhea in the past 4 weeks indicator		Child had malaria in the past 4 weeks indicator		Height-for-age z-score		Weight-for-age z-score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Male participated	-0.002	-0.013	0.041	-0.007	0.047	-0.064	0.208	0.227
	(0.025)	(0.030)	(0.035)	(0.040)	(0.131)	(0.151)	(0.126)	(0.141)
Household Controls	No	Yes	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes	No	Yes
Child gender-age controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	458	438	458	438	348	336	345	333
R-squared	0.000	0.049	0.003	0.073	0.000	0.097	0.008	0.088
Mean (SD) of dependent variable in the female participated group	0.073 (0.261)	0.073 (0.261)	0.139 (0.346)	0.139 (0.346)	-1.146 (1.240)	-1.146 (1.240)	-1.049 (1.008)	-1.049 (1.008)

	Child Health and Nutrition					
Dependent variable:	Weight-for-height z-score		Body-mass-index-for-age z-score		Overall, the respondent rates health of child as very healthy/somewhat healthy	
	(9)	(10)	(11)	(12)	(13)	(14)
Male participated	-0.108	-0.056	0.061	0.235	0.015	-0.004
	(0.140)	(0.159)	(0.147)	(0.172)	(0.016)	(0.019)
Household Controls	No	Yes	No	Yes	No	Yes
Basic School Controls	No	Yes	No	Yes	No	Yes
Child gender-age controls	No	Yes	No	Yes	No	Yes
Observations	301	292	343	331	449	429
R-squared	0.002	0.109	0.000	0.126	0.002	0.061
Mean (SD) of dependent variable in the female participated group	-0.457 (1.368)	-0.457 (1.368)	-0.395 (1.380)	-0.395 (1.380)	0.963 (0.190)	0.963 (0.190)

Notes: Refer to Table 4.6A
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

4.5. Conclusion

Applying a cluster-randomized controlled design, we examined the impacts of household water quality testing and information on health outcomes, and on sanitation and hygiene-related risk-mitigating behaviors. Baseline household summary statistics and orthogonality tests are used to validate the third party randomization process. Intention-to-treat (ITT), instrumental variable (IV) and differences-in-differences (DiD) estimators are used to study the impacts on health outcomes, and on sanitation and hygiene behaviors.

In this study, we find that there is high household interest in water quality issues, with about 71 percent of the households participating in water quality self-testing and also receiving information on water quality improvement, when they are targeted by the group-based training program. This high uptake rate is significant since in this context it was based on voluntary participation with no financial reward or inducement. This means new technologies on water quality could receive high interest given the "right" framework design.

After seven months of household participation in the information intervention, we find generally mixed results. In Chapter three, we find high private returns in terms of changes in safe water behaviors as a result of the household water quality testing and information. However, in this study we find little impacts on health outcomes, and on sanitation and hygiene-related risk-mitigating behaviors based on random assignment into any of the treatment arms (i.e. either school children intervention group or adult household members intervention group), limited evidence based on the differential/heterogeneous impacts as a function of the treatment arms and finally, little impacts based on the gender of participants. The results also indicate limited impacts on public health. In the context of this study, the intervention did not decrease the incidence of water, sanitation, and hygiene-related diseases compared to the control group. Similarly, we do not find statistically significant impacts on child health and nutrition outcomes, apart from surprising results of negative impacts on weight-for-age and height-for-age. These results could be due to attrition between survey waves and measurement error. This lack of public health impacts suggests that household water quality testing and information alone may not be enough to achieve the required improvements in health outcomes, and sanitation and hygiene-related risk-mitigating behaviors among households in resource poor settings. However, the high household willingness to participate suggests that relaxing information constraints for households in resource poor settings may be enough to generate increased adoption of water quality improvement technologies.

Could the lack of transmission of impacts from the household water quality testing and information intervention on health outcomes, and on sanitation and hygiene behaviors result from the research design, sample size, and survey implementation? The research was carefully designed to address potential observable challenges. One of the unforeseen challenges was the three months duration between the training exercise and the water quality self-testing due to administrative and logistical constraints. In this case, it seems unlikely to affect the intervention since each group had leader(s) from the various participating communities who could offer help in case any participant needed one. Again, each stage was supervised by the study team to address potential challenges. The training exercise was adequate since it included testing water from different sources (usually four different water sources) for the participants to identify the level of contamination of different water sources, use of community health nurses, use of local languages and finally, use of written training protocol to ensure even understanding among the treatment arms. Beliefs, illiteracy and previous experience with interventions could also hinder full compliance of the intervention. These, of course, are external factors, which cannot be influenced by this study. What we did was to control for some of these covariates during data analysis.

A key issue here is that the duration of seven months between experiment and follow-up surveys may be simply too short a time to identify impacts on health outcomes, and on sanitation and hygiene-related risk-mitigating behaviors. We believe however that while that may be true for health outcomes, behavior can be changed rapidly when not necessitating material investments or drastic reallocation of tasks and time in the household. Several of our behavioral or risk-prevention knowledge indicators can be argued to require no investment or time reallocation at all, yet they still do not pick up any impact of the intervention. Furthermore, these indicators are largely based on self-reported cases, which are affected by measurement error through "courtesy bias" and therefore limiting the statistical significance of our estimates (e.g. Günther and Schipper, 2013). In the future, a more objective measurement of these indicators could be useful. The sample size of 512 may be too small to generate enough power to detect effects on the self-reported incidence of water, sanitation and hygiene-related diseases. But a study by Karlan *et al*., (2014) on impacts of capital grant and weather (rainfall) insurance on agricultural investment decisions in Northern Ghana used similar sample size for multiarm experiment study. Although we compensate for this by conducting three follow-up surveys, in the future larger samples with longer study duration may generate additional evidence on the dynamics of the potential impacts of household water quality testing and information on health outcomes, sanitation, and hygiene-related risk-mitigating behaviors.

Survey implementation involved the use of experienced field data collectors and this should not present any challenge at all. It may also be possible that households responded to the intervention as only water quality issues and that may have reflected in results in Chapter three which shows improvement in safe water behaviors rather than health outcomes, and sanitation and hygiene-related risk-mitigating behaviors. In other words, households perceiving the study as only related to water quality issues but not as sanitation or hygiene promotion study may have influenced the lack of impacts on health outcomes, and sanitation and hygiene-related risk-mitigating behaviors. The nine water quality improvement messages might be too many and use of handouts instead of posters could be a factor in the compliance of the intervention. However, the information component plays complementary role to the water quality self-testing component and since we analyzed both jointly, it should take care of any inherent biases or weaknesses.

In conclusion, the findings from this study have relevant lessons for researchers and policy makers in health, and sanitation and hygiene sectors. The study contributes to the literature on the linkage of household water quality testing and information on reduction in water, sanitation and hygiene-related diseases. Our results on health impacts are similar to the only previous study (based on our knowledge) in this context (Brown *et al*., 2014), which found no statistically significant effect on reduction of diarrheal diseases. In some cases, their study even found increases in diarrhea incidences. Our findings on health impacts are also consistent with other studies on water quality improvement interventions, which had no statistically significant effects on diarrhea prevalence (Boisson *et al*., 2013). This requires further research to understand the complexities or dynamics of the potential impacts of household water quality testing and information on health outcomes, and sanitation and hygiene-related risk-mitigating behaviors. We learn from this study that new actors (for example, school children) and existing infrastructure or institutions (for example, households and public basic schools) could be useful in the dissemination of water quality information. The next challenge concerning this study is how to successfully up-scale the dissemination of water quality information to households in resource poor settings.

Chapter 5. Summary, Conclusions and Policy Implications

Health and nutrition are important ingredients in the measurement of welfare at both micro and macro levels such as poverty reduction, human capital formation, and economic growth. In this sense, achieving improved health and nutrition status will require the application of the systems approach in understanding the complex determinants and effective interventions, which will ensure efficient allocation of resources. More so, child health and nutrition status at the household level is an important public health issue. This chapter provides the summary of key empirical findings emanating from the study. Policy implications including limitations of the study and areas of future research are also highlighted.

5.1 Summary and Conclusions

The thesis addresses three research objectives constituting the empirical chapters: (1) to examine the synergetic effects or nexus or trade-offs between multipurpose water systems, and water, sanitation and hygiene practices on health and nutrition outcomes, (2) to estimate the impacts of household water quality testing and information on safe water behaviors, and (3) to assess the impacts of household water quality testing and information on health outcomes, and sanitation and hygiene-related risk-mitigating behaviors. The study relied on panel data collected from structured interviews of 512 households in the Ga South Municipality and Shai-Osudoku district in the Greater Accra region of Ghana. Four waves of data were collected between April 2014 and June 2015.

In literature, little attention has been paid to the interaction effects of multipurpose water systems, and water, sanitation and hygiene practices, and other household characteristics on child health and nutrition status. Understanding the role of multipurpose water systems and improved water, sanitation and hygiene practices on child health and nutrition status is relevant for public health. Chapter two of the study shows the empirical evidence of the relationship between multipurpose water systems, water, sanitation and hygiene practices, other household characteristics and health outcomes, using a panel data collected between 2014 and 2015 on households in southern Ghana. Random effects model is used to estimate the effects of participation in irrigated agriculture and fishing, improved water, sanitation and hygiene practices, and other household characteristics as the determinants of five indicators of child health and nutrition status in southern Ghana. The following conclusions are drawn from the study:

First, the findings complement those of previous studies. Household connected to the national grid (i.e. electricity) which is a proxy of urbanization significantly influences child health and nutrition status. Second, the results show other important determinants of short run child health and nutrition status (i.e. diarrhea prevalence and weight-for-height) and of long run child health and nutrition status (i.e. height-for-age and weight-for-age). For example, household use of the internet is positively associated with weight-for-age. Participation in irrigated agriculture is positively related with weight-for-age, weight-for-height and body mass index-for-age. In addition, open defecation increases diarrhea risk. Education of household head to the senior secondary school level and beyond decreases diarrhea risk and increases weight-for-age, weight-for-height, and body-mass-index-for-age. Third, household current income has mixed effects on child health and nutrition status. Higher current income is not positively associated with all the indicators of child health and nutrition status. The results meet the *apriori* expectations when height-for-age is used as the measure of child health and nutrition status. In the case of weight-for-height and body mass index-for-age, there is an inverse relationship between current household income. This supports similar claim by Wolfe and Behrman (1982) and consistent with the notion that current income could be affected by measurement error through reporting or courtesy bias, thereby affecting the validity of its use in estimating the determinants of child health and nutrition status.

In Chapter three, the study addresses an important question of what is the impacts of household water quality testing and information on risk avoidance behavior of poor water quality? The study also addresses the role of intra-household decision making or resource allocation on the demand for safe water behaviors. The Chapter focused on indicators of safe water behaviors, which are measurable and attainable within a short time of period such as water source choices; water storage practices; perception and knowledge of water quality and health risk; water transport, collection and handling techniques and water quantity and consumption/usage. Intention to treat (ITT), instrumental variables (IV) and differences-in-differences (DiD) are used to estimate the impacts. The results from the study found statistically significant impacts of household water quality testing and information on safe water behaviors. Specifically, the study finds that households that participated in water quality testing and information were 3.4 percentage points less likely to switch to surface water as the main drinking water source compared to their counterparts that received no water quality testing and information. Likewise, choice of improved secondary drinking water sources increased by 6.6 percentage points, covering of drinking water storage containers increased by 2.7 percentage points and there was time gain of 1.4 minutes per round trip of drinking water collection. However, there was less treatment of water and this partly confirms a previous study (Hamoudi *et al*., (2012)) where water quality testing led to switching to commercial water supply but not increase in water treatment. The results show incomplete or imperfect information as one of the explanations of less practice of safe water behaviors in resource poor settings and therefore water quality testing and information could be used as a social marketing strategy in promoting safe water behaviors in resource poor settings.

Among the treatment arms, school children were more effective in disseminating information on water quality than adult household members. For instance, households in the child treatment compared with adult treatment are more likely to use improved drinking water; less likely to use surface water as the main source of drinking water; more likely to use sachet water as the main source of drinking water; less distance to the main source of water; more closing and covering of containers; more likely to have clean storage containers and clean fetching equipment. This implies that the learning experiences of school children on water quality information were enough in convincing their households in adopting safe water behaviors. However, there is limited evidence on the role of gender in disseminating water quality information. This implies that public education programs providing specific information on water quality using school children could make a significant impact on improving safe water behaviors. The key point is that intra-household decision-making matters when it comes dissemination of water quality information.

In Chapter four, the study assesses the impact of household water quality testing and information on health outcomes and sanitation and hygiene behaviors. The health outcomes considered include self-reported diarrhea incidence, height for age, weight for age, weight for height and body mass index for age among children between zero and eight years of age. In the case of sanitation and hygiene behaviors, the study uses key indicators such as handwashing with soap, cleanliness of environment and children in the households and diarrhea prevention knowledge. This Chapter is analyzed using the same estimation strategy in Chapter three. More generally, the findings show no evidence that household water quality testing and information reduces diarrhea. In addition, there is no positive impact of the intervention on weight for height and body mass index for age. Surprisingly, there was a negative impact on weight for age and height for age, which may be due to measurement error and biases associated with anthropometric measurements such as high attrition between survey waves, among others. Furthermore, the impact on the primary outcome of hand washing with soap for sanitation and hygiene behaviors was negative. This is not as surprising as the participants are and for that matter, the households may have related to the intervention as only for water quality related issues but not as broader sanitation and hygiene promotion campaign.

The research design was adequate in addressing foreseeable challenges. The study relies on three follow-up surveys, which captures the various seasons in the study sites. The study also involved with the use of experienced field assistants who are also educated to the tertiary education level. The study sites comprise of both urban and rural areas, thereby addressing any inherent geographical biases. The findings are in tandem with other previous studies on water quality improvement interventions that found no statistically significant impact on health outcomes and sanitation and hygiene practices (Brown *et al*., 2014; Boisson *et al*., 2013). However, the lack of positive impacts on health outcomes and sanitation and hygiene behaviors could be due to several factors. The sample size may lack the statistical power in identifying recognizable impacts on diarrhea and other health outcomes. The study also relied on the self-reported measure of sanitation and hygiene behaviors, which could be affected by courtesy bias. There is the need for further research on how to obtain objective indicators for sanitation and hygiene behaviors. Another possible explanation could be due to a different direction of estimates for health outcomes among the different treatment groups. The lower incidence of diarrhea among children in the study sites as already highlighted by Boisson *et al*., 2013 could affect statistical power of the estimates of the potential effects among the treatment groups. In conclusion, results in Chapter four suggest that there are limited effects of household water quality testing and information on health outcomes and sanitation and hygiene-related risk-mitigating behaviors. Lastly, the study shows that households are imperfectly informed about their water quality and safety, which may be detrimental to health status or public health, and thus households in resource poor settings need information on water quality and safety through regular education campaigns including community outreach programs, training, and workshops.

5.2 Policy Implications

A number of policy relevant issues could be deduced from this study. The study confirms that improved water, sanitation, and hygiene practices are beneficial for the short run and long run child health and nutrition status. Other indicators with positive effects include connection of households to the national grid (i.e. electricity), improving internet access, and improving household irrigated agriculture opportunities. However, household's participation in fishing does not have statistically significant effects on child health and nutrition status. On child characteristics, there are strong effects of age on child health and nutrition status. Interestingly, the effects are uneven as they are highly dependent on the indicators used in measuring child health and nutrition status. Another major finding is that children in the study sample do not suffer from bias in favor of biological and male children in terms of risks associated with health and nutrition status. Policy makers and researchers trying to improve child health and nutrition status in resource poor settings will have to take into account the multiplicity of factors including water, sanitation and hygiene practices, social infrastructure and agriculture. Particularly, policies designed to improve irrigated agriculture in developing countries are more likely to have additional effects on a short run and long run nutritional status of children. Which types of irrigation systems are more beneficial to child health and nutrition status is an avenue for future research. In addition, a study using longer duration of data collection in a nationally representative sample may be of benefit in understanding the dynamics of child health and nutrition status in developing countries.

The study confirms previous literature that household water quality testing and information is associated with safe water behaviors. Adequate information on water quality and safety and options in improving it should be the relevant policy interventions. The findings on intra-household resource allocation show that school children are more effective in disseminating water quality information. However, there is limited gendered effect on safe water behaviors. Gendered treatment effects were largely found on water source choices and in most cases households with male participants were worse-off compared with those with female participants. The results imply that if policy makers are more concerned about improving safe water behaviors through the dissemination of water quality information, then intra-household variation or decision making process matters. In particular, school children could be used as “agents of change” in facilitating information drive in most developing countries in order to achieve safe water behaviors. Future research will show whether the effects presented in the thesis are either long term or short term.

However, there are limited beneficial effects on health outcomes and on sanitation and hygiene behaviors. The evidence of weak impacts of household water quality testing and information on health outcomes, and sanitation and hygiene behaviors show the relevance of combining information on water quality and safety with other interventions on water quality and quantity, sanitation and hygiene practices, and health and nutrition. The findings from the study address policy relevant questions about the potential effects of household water quality testing and information on health outcomes and sanitation and hygiene behaviors and underline the need for policy makers and promoters of water quality testing and information to present rigorous evidence on health impacts taking into consideration limitations of previous studies.

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Appendix

Table A1: Sample Frame Summaries and Observational Counts

Panel A: Experimental Blocks and Sample Frame 1				
AG-WATSAN Experiment	**Public Basic Schools**	**WATSAN Committee**	**Households**	
Water quality testing and information	8	-	256	
Control	8	-	256	
Total	**16**	**-**	**512**	
Panel B: Surveys				
Baseline Survey				
Targeted	-	-	512	
Completed	48	35	505	
First Follow-up Survey				
Targeted	-	-	505	
Completed	-	-	486	
Second Follow-up Survey				
Targeted	-	-	505	
Completed	-	-	478	
Endline Survey				
Targeted	-	-	505	
Completed	-	-	437	
Panel C: Sample Size Explanations for Each AG-WATSAN Experiment Block (Households)				
Segregation	**Water testing intervention**		**Control**	**Total**
Boys	64		64	**128**
Girls	64		64	**128**
Male parents	64		64	**128**
Female parents	64		64	**128**
Total	**256**		**256**	512

Table A2: Impacts on Diarrhea and Malaria Cases

	Diarrhea and Malaria Cases					
Dependent variable:	Household reported at least one diarrhea episode in the past one week	Household reported at least one diarrhea episode in the past two weeks	Household reported at least one diarrhea episode in the past one month	Household reported at least one malaria case in the past one week	Household reported at least one malaria case in the past two weeks	Household reported at least one malaria case in the past one month
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. ITT Estimation						
Treatment	0.012	0.004	0.011	-0.023	-0.025	-0.041
	(0.015)	(0.018)	(0.021)	(0.020)	(0.025)	(0.028)
Household Controls	Yes	Yes	Yes	Yes	Yes	Yes
Basic School Controls	Yes	Yes	Yes	Yes	Yes	Yes
Inclusion of baseline covariate of the dependent variable	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,243	1,243	1,243	1,332	1,332	1,332
R-squared	0.015	0.020	0.014	0.018	0.026	0.033
Mean (SD) of dependent variable in the comparison group	0.061 (0.239)	0.094 (0.293)	0.140 (0.347)	0.144 (0.351)	0.236 (0.425)	0.382 (0.486)
Panel B. Instrumental variable estimation: "participated" instrumented with "treatment"						
Participated	0.017	0.005	0.015	-0.031	-0.034	-0.055
	(0.020)	(0.024)	(0.029)	(0.027)	(0.033)	(0.037)
Household Controls	Yes	Yes	Yes	Yes	Yes	Yes
Basic School Controls	Yes	Yes	Yes	Yes	Yes	Yes
Inclusion of baseline covariate of the dependent variable	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,243	1,243	1,243	1,332	1,332	1,332
R-squared	0.016	0.021	0.015	0.018	0.026	0.032
Mean (SD) dependent variable in the comparison group	0.061 (0.239)	0.094 (0.293)	0.140 (0.347)	0.144 (0.351)	0.236 (0.425)	0.382 (0.486)

Notes: Robust standard errors in parentheses. Household and household head baseline controls include: household head is a male, head's age, head is married, head belongs to Ga/Adangbe ethnic group, head is a Christian, household is located in urban district (Ga South Municipal), household expenditure is high (i.e. 1 if the household is in percentiles 50-100 of annual expenditure), household undertakes irrigated agriculture, household has electricity, and number of female members under 15 years of age. Additional controls include baseline covariates of the dependent variables, household use of improved water and sanitation. Specifically, analyses on diarrhea indicators include diarrhea prevention knowledge and respondent indicating the use of clean water as the best way to prevent diarrhea. In the case of malaria indicators, we also include the household use of bed nets. Basic school controls include: school project contact person (i.e. SHEP coordinator) is a male.

Table A3: Differential Impacts on Diarrhea and Malaria Cases

	Diarrhea and Malaria Cases					
Dependent variable:	Household reported at least one diarrhea episode in the past one week	Household reported at least one diarrhea episode in the past two weeks	Household reported at least one diarrhea episode in the past one month	Household reported at least one malaria case in the past one week	Household reported at least one malaria case in the past two weeks	Household reported at least one malaria case in the past one month
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. ITT Estimation						
Child treatment	0.011	0.017	0.024	-0.029	-0.019	-0.016
	(0.020)	(0.024)	(0.028)	(0.025)	(0.031)	(0.035)
Adult treatment	0.014	-0.013	-0.004	-0.016	-0.033	-0.071*
	(0.020)	(0.025)	(0.029)	(0.029)	(0.034)	(0.038)
Household Controls	Yes	Yes	Yes	Yes	Yes	Yes
Basic School Controls	Yes	Yes	Yes	Yes	Yes	Yes
The inclusion of baseline covariate of the depen. variable	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,243	1,243	1,243	1,332	1,332	1,332
R-squared	0.015	0.021	0.015	0.018	0.026	0.034
Mean (SD) of dependent variable in the comparison group	0.061 (0.239)	0.094 (0.293)	0.140 (0.347)	0.144 (0.351)	0.236 (0.425)	0.382 (0.486)
Panel B. Instrumental variable estimation: "child participated" and "adult participated" instrumented with "child treatment" and "adult treatment"						
Child participated	0.013	0.021	0.029	-0.033	-0.021	-0.018
	(0.024)	(0.028)	(0.034)	(0.029)	(0.036)	(0.040)
Adult participated	0.024	-0.023	-0.009	-0.026	-0.057	-0.125*
	(0.034)	(0.042)	(0.050)	(0.050)	(0.060)	(0.068)
Household Controls	Yes	Yes	Yes	Yes	Yes	Yes
Basic School Controls	Yes	Yes	Yes	Yes	Yes	Yes
Inclusion of baseline covariate of the dependent variable	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,243	1,243	1,243	1,332	1,332	1,332
R-squared	0.017	0.019	0.013	0.018	0.026	0.030
Mean (SD) dependent variable in the comparison group	0.061 (0.239)	0.094 (0.293)	0.140 (0.347)	0.144 (0.351)	0.236 (0.425)	0.382 (0.486)

Notes: Household controls as in Table A2.

Table A4: Gendered Treatment Effects on Diarrhea and Malaria Cases

	Diarrhea and Malaria Cases					
Dependent variable:	Household reported at least one diarrhea episode in the past one week	Household reported at least one diarrhea episode in the past two weeks	Household reported at least one diarrhea episode in the past one month	Household reported at least one malaria case in the past one week	Household reported at least one malaria case in the past two weeks	Household reported at least one malaria case in the past one month
	(1)	(2)	(3)	(4)	(5)	(6)
Male participated	-0.031	-0.042	-0.030	-0.040	-0.059	0.020
	(0.028)	(0.032)	(0.039)	(0.036)	(0.043)	(0.050)
Household Controls	Yes	Yes	Yes	Yes	Yes	Yes
Basic School Controls	Yes	Yes	Yes	Yes	Yes	Yes
Inclusion of baseline covariate of the dependent variable	Yes	Yes	Yes	Yes	Yes	Yes
Observations	414	414	414	449	449	449
R-squared	0.040	0.054	0.055	0.036	0.049	0.043
Mean (SD) of dependent variable in the female participated group	0.089 (0.286)	0.128 (0.335)	0.195 (0.397)	0.136 (0.344)	0.230 (0.421)	0.354 (0.479)

Notes: Household controls as in Table A2.

Source: First, second and third follow-up round surveys in November/December 2014, January/February 2015, and May/June 2015.