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Household Water Quality Testing and Information: Identifying Impacts on Health Outcomes and Sanitation- and Hygiene-Related Risk-Mitigating Behaviors

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Abstract

Background: In 2014, a group of 512 households in multipurpose water systems and also relying on unimproved water, sanitation, and hygiene practices in the Greater Accra region of Ghana were randomly selected to participate in water quality self-testing and also receipt of information in the form of handouts on how to improve water quality.

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Objectives and Research Design: Using a cluster-randomized controlled design, we study the health, sanitation, and hygiene behavior impacts of the household water quality testing and information experiment. **Subjects:** The study has three arms: (1) adult household members, (2) schoolgoing children, and (3) control group. **Measures:** The study measures the effects on handwashing with soap, cleanliness of households, and prevalence of diarrhea and self-reported fever. We also address impacts on child health and nutrition outcomes, particularly diarrhea and anthropometric outcomes. **Results:** We show that there is high household willingness to participate in this intervention on water quality self-testing. About 7 months after households took part in the intervention, the study finds little impacts on health outcomes and on sanitation- and hygiene-related risk-mitigating behaviors, regardless of the intervention group, either schoolchildren or adult household members. Impacts (direction and extent) are rather homogeneous for most of the outcomes across treatment groups. **Conclusions:** The study discusses the implications of the findings and also offers several explanations for the lack of transmission of impacts from the household water quality testing and information intervention on health outcomes and on sanitation and hygiene behaviors.

Keywords
behavioral health care and policy, content area, economic evaluation, design and evaluation of programs and policies, methodology (if appropriate), program design and development, program implementation

Introduction

Globally, consumption of unsafe water affects about 663 million people (United Nations International Children's Emergency Fund and World Health Organization, 2015) and, in 2012, caused about 502,000 diarrhea deaths among children under 5 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, Tarvid, & Chao, 1998; Waddington, Snilstveit, White, & Fewtrell, 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 safe water behaviors by providing information and education to households on the essence of using safe 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 (Okyere, 2018; Okyere, Pangaribowo, Asante & von Braun, 2017; Brown, Hamoudi, Jeuland, & Turrini, 2014; Hamoudi et al., 2012; Jalan & Somanathan, 2008; Madajewicz et al., 2007). One peculiar characteristic with 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 (Okyere, 2018; Okyere, Pangaribowo, Asante & von Braun, 2017). Furthermore, in recent times, several studies have provided better understanding on the role of information in achieving safe water behaviors, including the use of improved water sources, water treatment, safe storage, and transport. 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, Cabral, & Colford, 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 vs. 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 on 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 (Hamoudi et al., 2012; Jalan & Somanathan, 2008; Madajewicz et al., 2007). 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 multiuse water systems. This study contributes to understanding how the intervention is linked to the outcome measures. For instance, how will water quality testing intervention lead to changes in hygiene and sanitation behaviors? Similarly, how the intervention lead to reduction in self-reported fevers or diarrhea? First, like all informational interventions, water quality testing is expected to lead to better knowledge of water quality issues and therefore lead to behavioral changes (Brown et al., 2014; Devoto, Duflo, Dupas, Pariente, & Pons, 2012; Hamoudi et al., 2012; Luoto, Levine, Albert, & Luby, 2014). Water quality testing complemented with information component presents credible evidence to households on the need to change behavior to reverse a potentially adverse condition of poor health outcomes. Since the water quality testing and information components are implemented simultaneously, we expect that the two components complement each other instead of them being substitutes. Of course, other studies could be undertaken to understand whether they are substitutes. Second, water quality testing and information can have multiplier effect on sanitation and hygiene behaviors since water, sanitation, and hygiene (WASH) practices are interlinked, and this is more evident in the literature of public health and development economics. This is so because sanitation and hygiene practices are better addressed through access to improved water and vice versa. Lastly, self-reported fevers and diarrhea are water-, sanitation-, and hygiene-related diseases, where behavioral changes in WASH through information interventions could help reduce it. Therefore, water quality testing and information is expected to lead to improved practices on water and sanitation (WATSAN), which will lead to less self-reported fevers and diarrhea. We achieve this aim by analyzing three follow-up surveys undertaken after 1, 3, and 7 months of households performing water quality self-testing and also 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 schoolgoing 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 multiarm randomized evaluation design in order to identify the best channel for the delivery of household water quality information. The randomized evaluation was designed to be able to differentiate between the delivery of the intervention between these two groups (i.e., schoolchildren vs. adults) for two main reasons: (1) to understand the role of intrahousehold allocation in the dissemination of water quality information in a developing country context and (2) to analyze the role of schoolchildren as "agent of change" in the delivery of health information in comparison to adults (see also Okyere, 2018; Okyere, Pangaribowo, Asante & von Braun, 2017). In Ghana's households, children and adults play different roles in WASH practices. For instance, supply of water and cleaning of dwelling are some of the tasks undertaken by children, while adults are tasked with providing financial support and also making decisions on resource allocation. The study contributes to how the delivery of intervention by different actors will affect sanitation and hygiene behaviors and health outcomes. In addition, we have expanded the analysis to include additional indicators on child health and nutrition and on sanitation and hygiene behaviors such as child height, child weight, child body mass index, cleanliness of dwelling, neatness of household, 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 control group (nonparticipants 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.

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 and self-reported fevers. 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 sanitation and hygiene practices (e.g., 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 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 7 months gap between the intervention and the final surveys may be too short to identify changes in nutrition outcomes.

After 7 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 85 and 55 percentage points participation or uptake rate for schoolchildren and adult household members, respectively, which is primarily attributable to our intervention since, at the time of our study, there was no market for such information or other type of exercise being undertaken in the study sites (see also Okyere and Asante, 2017 for additional information on participation). 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 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., schoolchildren vs. adult members of the household).

The rest of the study is structured as follows. The second section describes the household water quality testing and information experiment, randomization process, and data sources. The third section provides the estimation strategy. The fourth section presents the results. The final section discusses the results and also concludes the study.

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

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

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 multipurpose water settings. 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 also for irrigated agriculture or fishing purposes. Communities in the two sites rely on unimproved sanitation, while use of improved water sources is fairly high. Water source choices among households are diverse including use of sachet/bottled water, standpipe, borehole, rainwater, canals, rivers/streams/lakes, and so on. Household's use of multiple water sources is moderately high. Detail description of the WATSAN services in the administrative districts could be found in previous studies (Okyere, 2018; Okyere, Pangaribowo, Asante & von Braun, 2017; Okyere and Asante, 2017).

Experimental Design and Sample Selection

The study (including consent and assent form) had ethical approval from two research institutions. We conducted an institutional survey with public basic schools and 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. Sixteen 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, 1 public basic school was selected (i.e., 16 public basic schools in 16 communities). We obtained the student register for students from Grades 5 to 8 in each public basic school, which sums to 4,651 student population. From this list, 512 students (i.e., 32 students per public basic school) were randomly selected using Stata version 12.1 software (StataCorp 2013). 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 km 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 control 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 schoolchildren intervention group, schoolchildren 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 also 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" (Torgerson & Roberts, 1999; Viera

& Bangdiwala, 2007). 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 analyses, we combined the two control groups (i.e., schoolchildren control group and adult household members' control group) as one and redefined it as control 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 (i.e., July 2014), we rolled-out the intervention for the two treatment groups (i.e., schoolchildren intervention group and adult household members' intervention group). In the schoolchildren intervention group, as the name suggests, we used schoolchildren for the intervention, and, in the adult household members' intervention group, we relied on adult household members (such as husband/father and wife/mother of the students) for the intervention. Note that public basic schools are the unit of randomization. The design targets only adults with school-age children due to the use of the public basic schools as the primary 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 also 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 selected schoolchildren.

The Round 1 of the intervention involved two phases. The first phase involved group-based training on the use of the water testing kits. This was completed by hired assistants (community health nurses) in July 2014. The second phase involved actual water quality self-testing that 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 handouts based on previous studies (Brown et al., 2014; 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, rainwater, 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 to November 2014, water samples from both point-of-source (POS) and point-of-use (POU) in the control 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 schoolchildren and adult household members) to redeliver the same water quality improvement messages (i.e., Round 2 experiment). The mode of delivery of the handouts was based on the treatment assignment, with the distribution of the handouts given to schoolchildren in the children treatment group and adults (parents/guardians) in the adult treatment group. Then two copies of the handouts containing the water quality improvement messages were left with the households for reference and also for discussions with other household members. The randomization design, time line of the experiment, and data collection are presented in Figure 1. The detailed experimental design has been shown before (Okyere, 2018; Okyere, Pangaribowo, Asante & von Braun, 2017; Okyere and Asante, 2017).

Data Collection and Summary Statistics

In the 512 randomly selected households from the 16 communities, a socioeconomic survey in addition to water sample analysis (both laboratory and on-field) of both POS and POU were undertaken in April to May 2014. In April to May 2014, hired field data collectors visited the households to conduct baseline interview with the household heads or adults who are most knowledgeable on WASH issues (for instance, spouse). In all, the baseline survey yielded interviews with 505 households, a success rate of 98.6%. The baseline survey involved asking respondents for information on current WASH behaviors. The baseline survey also captured

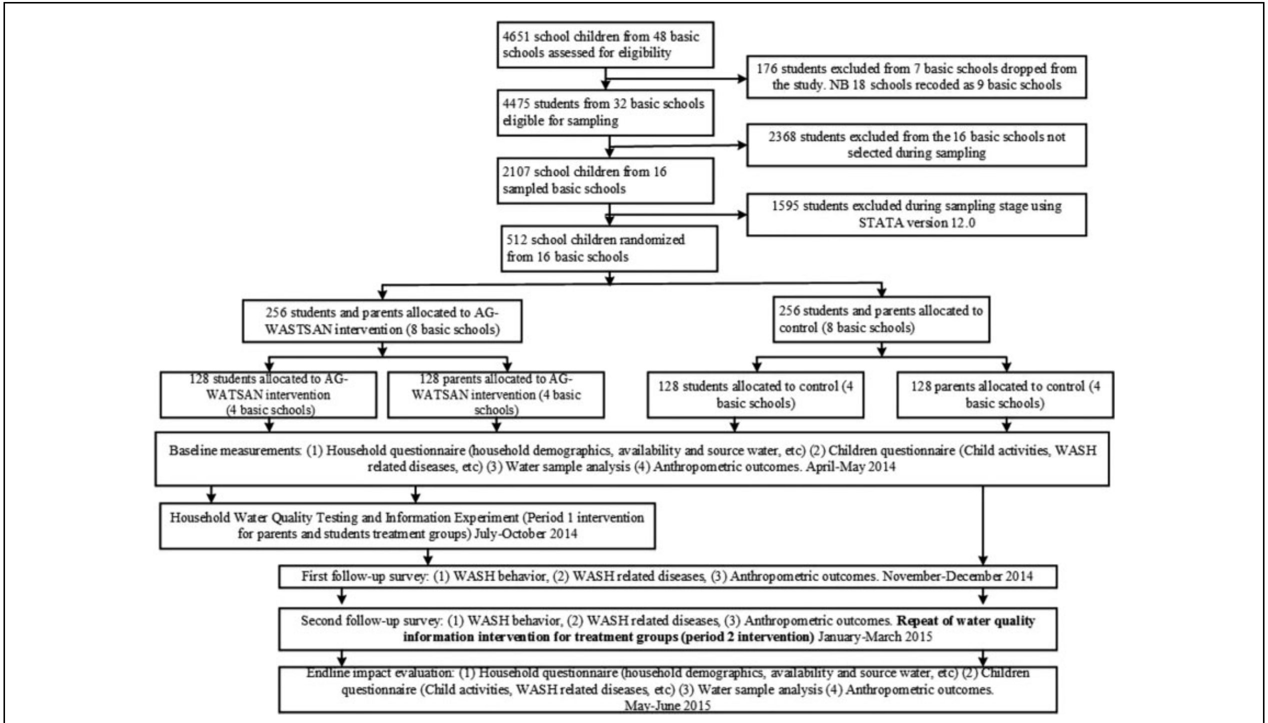

Figure 1. Flowchart of randomization design and time lines.

detailed information on socioeconomic characteristics. Anthropometric measurements for children under 8 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 WASH behaviors and health indicators. We also took anthropometric measurements of all children under 8 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., 3–4 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 to June 2015 (i.e., about 2–3 months after completion of Round 2 experiment), we completed the end line survey using largely the baseline survey instruments. At the end of the end line survey, we successfully enumerated 437 households. Overall attrition rate is moderate: About 97.2% of the households interviewed during baseline survey were successfully enumerated in at least two of the three follow-up surveys, while about 82.4% of the households were enumerated in all three follow-up surveys. For instance, in wave 2, there were 115 children treatment households and 127 adult treatment households. In wave 3, there were 118 children treatment households and 115 adult treatment households. Finally, in wave 4, there were 109 children treatment households and 108 adult treatment households. Attrition rate is not statistically significantly related to treatment assignment: The estimated coefficient on child treatment is 0.166 (s.e. 0.260) and that of adult treatment is 0.057 (s.e. 0.272).

Using a procedure that has been shown before (Okyere, Pangaribowo, Asante & von Braun, 2017), we assess the statistical similarity of the households in the study arms at the baseline. Summary statistics and Bonferroni multiple comparison tests are presented in Online Appendix Table A1. We show the F-test of each covariate among the three study arms (results in column 5) and report p value, which test the null hypothesis of no statistically significant difference among the study arms. Most of the household health outcomes and sanitation- and hygiene-related risk-mitigating behaviors are similar across the study arms (Online Appendix Table A1). Of 15 F-tests reported in Online Appendix Table A1, only 2 were statistically significantly different from 0 at the 90% and 99% confidence levels. We run regressions under the impacts subsection by including baseline covariates as robustness check for the estimated results.

Due to space reasons, we will not present the summary statistics and Bonferroni multiple comparison tests for household socioeconomic characteristics. The socioeconomic characteristics that are used as baseline household covariates in the impact analyses have been shown before (Okyere, Pangaribowo, Asante & von Braun, 2017). The socioeconomic characteristics are extremely similar across the three study arms. These baseline covariates have been reported under the tables for the impact analyses.

We briefly mention here some of the interesting facts observed in Online Appendix Table A1. At baseline, about 84.8% of the households reported handwashing with soap or detergent (Online Appendix Table A1, Panel A). About 83.4% of the households had latrine/toilet that was very clean or clean enough based on enumerator observations (Online Appendix Table A1, Panel A). Self-reported fevers cases are high with about 35.2% of the households reporting at least one case in the past 1 month preceding the survey, while diarrhea rate is low with 15.4% of the households reporting at least one case in the past 1 month preceding the survey (Online Appendix Table A1, Panel B). In summary, while the study was specifically targeted at communities within multiuse water systems, some of the indicators are similar to national averages. For example, stunting in the survey was about 21%, which is close to the national average of 24% based on the 2015 Multiple Indicator Cluster Survey. In addition, access to improved water that was 73% in the data was relatively lower than the national average of about 80% reported in 2015, while improved sanitation of 44% was higher than the national average of 14.90% in 2015.

Estimation Strategy

We explore the impacts of the intervention as a function of the treatment arms. Based on the experimental evaluation design, already described under the Experimental Design and Sample Selection section and has been shown before (Okyere, 2018; Okyere, Pangaribowo, Asante & von Braun, 2017), the reduced form basic equation could be specified as:

$$Y_{it} = \mu_0 + \beta_1 C_{it} + \beta_2 A_{it} + X'_{it}\pi_1 + (C_{it} \times X_i)\beta_3 + (A_{it} \times X_i)\beta_4 + D_c + \varepsilon_{1it}, \quad (1)$$

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 C_{it} is a dummy variable that household i was assigned to schoolchildren intervention group in time t, and

A_{it} is an indicator variable that household i was assigned to adult household members intervention group in time t. $X_{it}^{'}$ is a set of baseline household characteristics, which is used in some of the specifications as robustness checks, while ε_{1it} is the disturbance term. D_c is wave fixed effects. β_1 indicates the average differences between schoolchildren intervention group and control group for the respective outcome variables, and β_2 indicates the average differences between adult household members intervention group and control group for the respective outcome variables, which are the intention-to-treat (ITT) estimates. The reduced form (ITT) parameter derived from Equation 1 estimates the causal effect of being assigned to household water quality testing and information experiment. Separately, the study undertakes analyses comparing the outcomes between child treatment versus the adult treatment and the results are reported in Table 1, columns 5 and 6.

All the equations are estimated using linear approximation, although most of the outcome variables are binary. Following from previous studies (Bloom et al., 2006; Fujiwara & Wantchekon, 2013; Heß, 2017; Rosenbaum, 2002), for all estimated coefficients, the study reports clustered standard errors in addition to *p* values of two-sided randomization inference of no treatment effects. Randomization inference is useful in estimating treatment effects for both randomized and observational studies with small sample size or clusters (Duflo, Glennerster, & Kremer, 2007; Heß, 2017; McKenzie, 2017; Rosenbaum, 2002; Young, 2019). The Stata's *ritest* command developed by Heß (2017) is used in performing the randomization inference with placebo replications of 2,000 times; this number of replications was chosen based on previous studies (McKenzie, 2017; Young, 2019) that the results do not change much after 2,000 replications. We report only results with controls included in the analyses and, finally, all data sets are unweighted.

Results

This section presents the results on the impacts of household water quality testing and information experiment on the health outcomes and sanitation- and hygiene-related risk-mitigating behaviors. We follow previous studies (Devoto et al., 2012; Fujiwara & Wantchekon, 2013; Karlan, Kutsoati, McMillan, & Udry, 2011; Karlan, Osei, Osei-Akoto, & Udry, 2014; Kremer, Leino, Miguel & Zwane, 2011; Okyere, 2018; Okyere, Pangaribowo, Asante & von Braun, 2017) in terms of presentation of results.

Table 1. Impacts on Health Outcomes and on Sanitation and Hygiene Practices.

Dependent Variable	Mean (*SD*) of the Control Group (1)	Child Treatment (2)	Adult Treatment (3)	Randomization Inference *p* Value (4)	Child Treatment–Adult Treatment (5)	Randomization Inference *p* Value (6)
Panel A: Sanitation and hygiene practices						
Last time respondent used soap/detergent to wash hands	.929 (0.257)	−.009 (.020)	−.038* (.022)	.301	.035 (.027)	.244
Surrounding of household is clean/average	.804 (0.397)	−.003 (.028)	.076** (.031)	.058*	−.089** (.036)	.063*
Latrine or toilet is very clean/clean enough	.819 (0.386)	−.069 (.052)	.140** (.064)	.043**	−.204*** (.067)	.093*
Respondent mentioned at least three instances of handwashing yesterday	.733 (0.442)	.009 (.029)	.011 (.031)	.974	−.006 (.037)	.883
Panel B: Diarrhea and self-reported fever cases						
Household reported at least one diarrhea episode in the past 1 month	.140 (0.347)	.007 (.028)	.005 (.030)	.962	.007 (.037)	.899
Household reported at least one self-reported fever case in the past 1 month	.382 (0.486)	−.031 (.037)	−.033 (.039)	.975	.001 (.046)	.991

(continued)

Table 1. (continued)

Dependent Variable	Mean (*SD*) of the Control Group (1)	Child Treatment (2)	Adult Treatment (3)	Randomization Inference *p* Value (4)	Child Treatment–Adult Treatment (5)	Randomization Inference *p* Value (6)
Panel C: Child health and nutrition						
Child had diarrhea in the past 4 weeks indicator	.052 (0.222)	.022 (.019)	.001 (.020)	.511	.011 (.028)	.763
Height-for-age z-score	−.910 (1.260)	−.326*** (.118)	−.135 (.119)	.327	−.125 (.156)	.535
Weight-for-age z-score	−.769 (1.083)	−.212** (.108)	.051 (.109)	.090*	−.281* (.147)	.078*
Weight-for-height z-score	−.413 (1.273)	−.033 (.138)	.179 (.135)	.329	−.239 (.181)	.263
Body-mass-index-for-age z-score	−.326 (1.307)	.101 (.127)	.191 (.129)	.6290	−.145 (.174)	.435

Source. First, second, and third follow-up round surveys in November/December 2014, January/February 2015, and May/June 2015.
Note. The observations for cleanliness of latrine are for only households with latrine/toilet. Clustered standard errors are 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. Analysis for health outcomes include additional controls such as household use improved water and sanitation. Specifically, analyses on diarrhea indicators include diarrhea prevention knowledge and respondent indicating use of clean water as the best way to prevent diarrhea. In the case of self-reported fevers, we also include household use of bed nets. Analysis for child health and nutrition includes child gender–age controls such as gender of child, linear and square of the age in years. All analyses include wave fixed effects, receipt of water, sanitation, and hygiene information at baseline and its interaction with the treatment variables.
*Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

We explore the treatment effects as a function of assignment into the study arms. We use an instrumental variable (IV) approach to estimate the effects of treatment assignment on participation in the intervention. The first-stage regression shows very strong relationship between treatment assignment and participation in the experiment (Online Appendix Table A2, columns 1 and 2). Treatment assignment leads to participation by households in the schoolchildren treatment group of 85.2 percentage points (s.e. 2.1 percentage points), while participation by households in the adult household members intervention group was 55.1 percentage points (s.e. 3.2 percentage points). The uptake rates are high and quite significant, since the participants were not motivated with any financial rewards including funds for transportation, among others. Günther and Schipper (2013) found usage rate of 88% for an intervention on the distribution of improved water containers in Benin. Devoto, Duflo, Dupas, Pariente, and Pons (2012) found that piped water connection was 69% in treatment households after an encouragement design experiment in urban Morocco.

Children Versus Parents: Comparison of Treatment Effects on Health Outcomes, Sanitation, and Hygiene Practices

Impacts on sanitation and hygiene practices. Table 1, Panel A, shows the differential impacts on sanitation and hygiene practices. The results show that use of soap or detergent for handwashing decreased by 3.8 percentage points in households in the adult household members' intervention group. The result is significant in the standard *t* test but not statistically significant in the randomization inference test. Panel A also reports the differential effects on cleanliness of surroundings and latrine/toilet. The study finds large and substantial improvement in the cleanliness of surroundings and latrine/toilet. For instance, households in the adult household members' intervention group were 7.6 percentage points more likely to have surroundings of their dwellings to be clean or average (s.e. 3.1 percentage points, relative to average value of 80.4% in the control group).

In addition, households in the adult household members' intervention are 14 percentage points more likely to have toilet/latrine observed to be very clean or clean enough (s.e. 6.4 percentage points, relative to average value of 81.9% in the control group). The results are significant in both the standard *t* test and randomization inference test. There is no statistically significant effect for households in the schoolchildren intervention groups. The results suggest that the intervention induces changes in some sanitation and hygiene behaviors in the adult household members' intervention group and not that of schoolchildren intervention group. This is confirmed by the results in columns 5 and 6 that show that households in the schoolchildren intervention group have lower effect size compared to their counterparts in the adult household members intervention group. The results for those households in the adult treatment group suggest that the intervention induces sanitation and hygiene behavior changes that involve limited financial investment. Cleaning of latrines and surroundings of dwelling is usually done with brooms that are less costly than purchase of soap or detergent (which will be perceived to be more costly in terms of time and financial resources needed). However, delivering the information through children had no effect, and this may suggest that, in this study context, there are barriers to information in improving sanitation and hygiene behaviors using children (i.e. those who are not the primary decision makers).

Impacts on diarrhea and self-reported fever cases. We do not find statistically significant effect in terms of reduction in diarrhea and self-reported fever cases (Table 1, Panel B). We explore the differential effects as functions of additional baseline covariates to the standard baseline controls including, for instance, household use of improved WATSAN. Specifically, for the diarrhea analysis, we include also the diarrhea prevention knowledge and also use of clean water as the best means of preventing diarrhea. For the analysis on self-reported fever cases, we include 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 self-reported fevers reduction, even as we control for these additional covariates.

Impacts on child health and nutrition. We estimate the impacts of the household water quality testing and information intervention on child health (diarrhea in past 4 weeks preceding the surveys) and nutrition (anthropometrics) and the results are presented in Table A1, Panel C. We expand the standard household baseline controls to include child-specific variables such gender of child and age of the child in the regressions.

We find that children in the schoolchildren intervention group are 0.326 standard deviations lower in terms of height-for-age z-score (relative to average value of -0.910 standard deviations in the control group). The result is only significant for the standard t test but not the randomization inference test. Although children in the adult treatment have a negative effect, the result is not significant. Also, the result shows that children in the schoolchildren intervention group are 0.212 standard deviations lower in terms of weight-for-age *z*-score (relative to average value of −0.769 standard deviations in the control group) than their counterparts in the control group. The result is significant in both the standard *t* test and randomization inference test. In the case of weight for age, children the schoolchildren intervention group were lower when compared to their counterparts in the adult treatment group (Table 1, Panel C, columns 5 and 6). The results for children in the adult household members intervention group are not statistically significant in any of the test (Panel C). In addition, the interaction terms between baseline ever receipt of WASH information and adult household members' intervention group are negative and statistically significant for weight for age, weight for height, and body mass index for age. This implies that the results could be driven by previous knowledge on WASH information, and therefore its combination with the current intervention could not generate the "desirable" positive effects on nutrition outcomes. In addition, these results could be driven by differential children attrition rate between survey waves. For instance, while children with anthropometrics measured in only one survey wave after baseline was similar (0.111 [s.e. 0.025] for control group, 0.128 [s.e. 0.038] in the schoolchildren intervention, and 0.141 [s.e. 0.040] for adult household members intervention), those without anthropmetric outcomes in at least three survey waves have some differences (0.327 [s.e. 0.037] in the control group, 0.244 [s.e. 0.049] for schoolchildren intervention group, and 0.192 [s.e. 0.045] for adult household members). Further analysis shows statistically significant difference between children in adult treatment groups and those of the control group (coefficient of −0.422 [s.e. 0.193], which was significant at 5% level). However, these results are not so surprising, since these indicators represent the long-run nutritional status of children, and the duration of the follow-up surveys of about 7 months after the intervention maybe too short a time to observe improvement in long-run anthropometric outcomes. On the short-run nutritional status, we find no statistically significant effect on weight for height and body mass index.

Discussion and 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 summary statistics and Bonferroni multiple comparison tests are used to validate the third-party randomization process. ITT is 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 85% and 55% of schoolchildren and adult household members, respectively, participating in water quality self-testing and also receiving information on water quality improvement, when they are targeted by 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 7 months of household participation in the water quality testing and information intervention, we find generally mixed results. In Okyere, 2018; Okyere, Pangaribowo, Asante & von Braun, 2017, there are impacts of the intervention on safe water behaviors. However, in this study, we find little impacts on health outcomes and on sanitation- and hygiene-related risk-mitigating behaviors based on the treatment groups. 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 largely do not find statistically significant impacts on child health and nutrition outcomes, apart from negative impacts on weight for age and height for age. These results could be due to children attrition between survey waves. In general, the lack of impacts on the health outcomes may not be surprising, as the study finds limited impacts on the intermediate outcomes (i.e. sanitation and hygiene behaviors). The impacts on health are expected to be conditional on that of the intermediate outcomes. Therefore the results could indicate weak statistical power in detecting impacts on health emanating from limited impacts on the intermediate outcomes. The lack of public health impacts (particularly on handwashing with soap/detergent, diarrhea, and self-reported fevers) suggests that household water quality testing and information alone may not be enough to induce the required improvements in sanitation- and hygiene-related risk-mitigating behaviors and achieve the targeted health outcomes among households in resource poor settings. The evidence of weak impacts of household water quality testing and information on health outcomes and sanitation and hygiene behaviors shows 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. 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.

In cases where we find impacts on sanitation and hygiene behaviors, the results are largely driven by the adult household members' intervention group. This is not surprising as the respondents in the surveys were adult household members who were knowledgeable on WASH in the households. In addition, this group might have understood the intervention in its broader sense on WASH but not only related to water quality issues alone.

It may be possible that households (particularly those in the schoolchildren intervention group) understood the intervention as only a water quality issue experiment due to the use of water testing kits, which is uncommon in the study sites. That may have reflected in results in Okyere, 2018 and Okyere, Pangaribowo, Asante & von Braun, 2017 which show improvement in safe water behaviors rather than the health outcomes and sanitation- and hygiene-related risk-mitigating behaviors that we tried to capture here. In other words, the lack of impacts on health outcomes and sanitation- and hygiene-related risk-mitigating behaviors may have been influenced by children perceiving the study as only related to water quality issues but not as sanitation or hygiene promotion study. Furthermore, the nine water quality improvement messages that include specific information on water collection, transport, and handling in addition to sanitation and hygiene behavior of handwashing with soap (refer to Experimental Design and Sample Selection section for details on information component) might be too many, and use of handouts instead of posters could also be a factor in the compliance of the intervention. However, the information component plays a complimentary role to the water quality self-testing component, and since we analyzed both jointly, it should take care of any inherent biases or weaknesses.

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 3-month 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 (Okyere, 2018; Okyere, Pangaribowo, Asante & von Braun, 2017). 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 7 months between experiment and follow-up surveys may be simply too short a time to identify impacts on health outcomes (particularly on long-run nutritional indicators) and on sanitation- and hygiene-related risk-mitigating behaviors. We believe, however, that while that may be true for health and nutritional 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 that are affected by measurement error through "courtesy bias" and therefore limiting the statistical significance of our estimates (see also Günther & Schipper, 2013). In the future, a more objective measurement of these indicators could be useful. The sample size of 512 in two districts and 16 communities and its environs may be too small to generate enough power to detect effects on self-reported incidence of WASH-related diseases. 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 and on sanitation- and hygiene-related risk-mitigating behaviors.

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 literature on the linkage of household water quality testing and information on reduction in WASH-related diseases. Despite our elaborate intervention and study design, 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. In particular, this study points at the multiple pathways to improved health and nutrition in the agriculture–water–sanitation nexus, which require further analysis: Improving the water quality at the point of use cannot lead to positive health impacts without behavioral change both in the WATSAN/hygiene spheres, and not all behaviors are easy to change. What we further learn from this study is that new actors (e.g., schoolchildren) and existing infrastructure or institutions (e.g., households and public basic schools) could be useful in the dissemination of water quality information. In that respect, the next challenge is to successfully upscale the dissemination of water quality information to households in resource poor settings.

Authors' Note

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Supplemental Material

Supplemental material for this article is available online

References

Bloom, E., Bhushan, I., Clingingsmith, D., Hung, R., King, E., Kremer, M., … Schwartz, B. (2006). *Contracting for health: Evidence from Cambodia*. New York, NY: Mimeo.

Boisson, S., Stevenson, M., Shapiro, L., Kumar, V., Singh, L. P., Ward, D., & Clasen, T. (2013). Effect of household-based drinking water chlorination on diarrhoea among children under five in Orissa, India: A double-blind randomised placebo-controlled trial. *PLoS Medicine*, *10*, e1001497. pp. 1–12.

Brown, J., Hamoudi, A., Jeuland, M., & Turrini, G. (2014). Heterogeneous effects of information on household behaviors to improve water quality. *The Duke Environmental and Energy Economic Working paper EE 14-06*, pp. 1–44.

Devoto, F., Duflo, E., Dupas, P., Pariente, W., & Pons, V (2012). Happiness on tap: Piped water adoption in Urban Morocco. *American Economic Journal: Economic Policy*, *4*, 68–99.

Duflo, E., Glennerster, R., & Kremer, M. (2007). *Using randomization in development economics research: A toolkit*. *Discussion Paper No. 6059*, Centre for Economic Policy Research, UK. Retrieved August 30, 2019, from www.cepr.org/pubs/dps/DP6059.asp

Finkelstein, A., Taubman, S., Wright, B., Bernstein, M., Gruber, J., Newhouse, J. P., Allen, H., & Baicker, K. & the Oregon Health Study Group. (2012). The Oregon health insurance experiment: Evidence from the first year. *The Quarterly Journal of Economics*, *127*, 1057–1106.

Fujiwara, T., & Wantchekon, L. (2013). Can informed public deliberation overcome clientelism? Experimental evidence from Benin. *American Economic Journal: Applied Economics*, *5*, 241–255.

Günther, I., & Schipper, Y. (2013). Pumps, germs and storage: The impact of improved water containers on water quality and health. *Health Economics*, *22*, 757–774.

Hamoudi, A., Jeuland, M., Lombardo, S., Patil, S., Pattanayak, S. K., & Rai, S. (2012). The effect of water quality testing on household behavior: Evidence from an experiment in rural India. *American Journal of Tropical Medicine and Hygiene*, *87*, 18–22.

Heß, S. (2017). Randomization inference with Stata: A guide and software. *Stata Journal*, *17*, 630–651.

Jalan, J., & Somanathan, E. (2008). The importance of being informed: Experimental evidence on demand for environmental quality. *Journal of Development Economics*, *87*, 14–28.

Karlan, D., Kutsoati, E., McMillan, M., & Udry, C. (2011). Crop price indemnified loans for farmers: A pilot experiment in rural Ghana. *The Journal of Risk and Insurance*, *78*, 37–55.

Karlan, D., Osei, R. D., Osei-Akoto, I., & Udry, C. (2014). Agricultural decisions after relaxing credit and risk constraints. *The Quarterly Journal of Economics*, *129*, 597–652.

Kremer, M., Leino, J., Miguel, E., & Zwane, A. P. (2011). Spring cleaning: Rural water impacts, valuation, and property rights institutions. *The Quarterly Journal of Economics*, *126*, 145–205.

Lucas, P. J., Cabral, C., & Colford, J. M. Jr. (2011). Dissemination of drinking water contamination data to consumers: A systematic review of impact on consumer behaviors. *PLoS One*, *6*, 1–9.

Luoto, J., Levine, D., Albert, J., & Luby, S. (2014). Nudging to use: Achieving safe water behaviors in Kenya and Bangladesh. *Journal of Development Economics*, *110*, 13–21.

Madajewicz, M., Pfaff, A., van Geen, A., Graziano, J., Hussein, I., Momotaj, H., ... Ahsan, H. (2007). Can information alone change behavior? Response to arsenic contamination of groundwater in Bangladesh. *Journal of Development Economics*, *84*, 731–754.

McKenzie, D. (2017). Finally, a way to do easy randomization inference in Stata! Published on development impact. Retrieved August 30, 2019, from http://blogs.worldbank.org/impactevaluations/finally-way-do-easy-randomization-inference-stata

Okyere, C. Y. (2018). Water quality in multipurpose water systems, sanitation, hygiene and health outcomes in Ghana. Doctoral thesis submitted to Faculty of Agriculture, University of Bonn, Germany, 1–183. Available online at http://hss.ulb.uni-bonn.de/2018/4854/4854.htm

Okyere, C. Y., & Asante, F. A. (2017). Perceptions and determinants of households' participation in a randomized evaluation on water quality testing and information in Southern Ghana. *Water Policy*, *19*, 1206–1224. Available online at http://wp.iwaponline.com/content/19/6/1206

Okyere, C. Y., Pangaribowo, E. H., Asante, F. A., & von Braun, J. (2017). The impacts of household water quality testing and information on safe water behaviors: Evidence from a randomized experiment in Ghana. ZEF-Discussion Papers on Development Policy No. 234, Center for Development Research, Bonn, March, pp. 57. Available online at http://www.zef.de/uploads/tx_zefnews/zef_dp_234.pdf

Prüss-Ustün, A., Bartram, J., Clasen, T., Colford, J. M. Jr., Cumming, O., Curtis, V., . . . Cairncross, S. (2014). Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: A retrospective analysis of data from 145 countries. *Tropical Medicine and International Health*, *19*, 894–905.

Rosenbaum, P. R. (2002). Covariance adjustment in randomized experiments and observational studies (with discussion). *Statistical Science*, *17*, 286–327.

StataCorp. (2013). *Stata statistical software: Release 12.1*. College Station, TX.

Torgerson, D. J., & Roberts, C. (1999). Randomisation methods: Concealment. *British Medical Journal*, *319*, 375–376.

United Nations International Children's Emergency Fund and World Health Organization. (2015). *Progress on sanitation and drinking water—2015 update and MDG assessment*. Geneva, Switzerland: WHO.

Varley, R. C. G., Tarvid, J., & Chao, D. N. W. (1998). A reassessment of the cost-effectiveness of water and sanitation interventions in programmes for controlling childhood diarrhoea. *Bulletin of the World Health Organization*, *76*, 617–631.

Viera, A. J., & Bangdiwala, S. I. (2007). Eliminating bias in randomized controlled trials: Importance of allocation concealment and masking. *Family Medicine*, *39*, 132–137.

Waddington, H., Snilstveit, B., White, H., & Fewtrell, L. (2009). Water, sanitation and hygiene interventions to combat childhood diarrhoea in developing countries. In *International initiative for impact evaluation (3ie) synthetic review 001* (pp. 1–117). New Delhi, India: 3ie.

Young, A. (2019). Channeling fisher: Randomization tests and the statistical insignificance of seemingly significant experimental results. *The Quarterly Journal of Economics*, *134*, 557–598.

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