Water, Sanitation and the Risk of Chronic Conditions among Older Persons in Ghana: Results from the WHO Study on Global AGEing and adult health (SAGE) Wave 2

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Research article

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Abstract

Objective

Water and sanitation have been related to the health of populations, yet, the effects of these factors on the occurrence of chronic conditions (CC) in later life have been least explored. This study examines the association of CC with water and sanitation among older Ghanaians and whether the associations are moderated by gender and residence.

Methods

Data from the WHO-SAGE Wave 2 comprising of 4735 adults aged ≥ 50 years were analyzed in this study. The primary outcome was CC and the exposures included sources of water, sanitation facilities and the sharing of sanitation facilities. Generalized logistic regression models estimated the effects of water and sanitation indicators on the occurrence of CC.

Results

Overall, 18.8% of the sample reported at least one CC. Compared to men and rural residents, women and urban residents respectively were more likely to report CC ($p < 0.001$). After full adjustments, logistic regressions showed that the use of unimproved sanitation (OR = 1.732, CI: 1.377–5.418) and sharing of sanitation facilities (OR = 1.624, CI: 1.095–1.320) were associated with higher odds of CC. However, the use of water did not reach significance ($p = 0.125$). We found a significant interaction effect for type of toilet $\times$ gender (OR = 3.498, CI: 1.744–16.442), source of water $\times$ residence (OR = 5.935, CI: 1.320–26.685) and type of toilet $\times$ residence (OR = 1.998, CI: 1.462–8.642).

Conclusions

The use of unimproved sanitation facilities and the sharing of sanitation facilities are associated with the occurrence of CC among older people. Policy and public health interventions targeted at improving the health and well-being of older people should conspicuously include improving access to sanitation services.

Introduction

The Joint Monitoring Program (JMP) of the World Health Organisation (WHO) and the United Nations Children's Fund (UNICEF) estimated that in 2017, 435 million people globally used water from unprotected wells and springs, and a further 144 million used untreated surface water. With regard to sanitation, it was estimated that 701 million people used unimproved sanitation facilities, and 673 million still practised open defecation. Inadequate Water, Sanitation and Hygiene (WASH) has been linked to morbidity and mortality from WASH-related diseases, especially among vulnerable groups such as the poor and children under 5 years. Conversely, provision of adequate WASH services has been related to saving the time spent in fetching water and accessing sanitation facilities, health care savings, more time for women and girls in school, improved school attendance and general socio-economic development.

Inclusive WASH service provision requires consideration of groups of people such as the older adults and people living with disabilities. However, limited data is available on the effects of WASH among the older people, although sparse evidence suggests the importance of increasing access through age-friendly technologies. WASH-related challenges among older people may be striking particularly in low- and middle-income countries (LMICs) because these people largely rely on other demographic cohorts for safe WASH services.

The absolute numbers and the proportions of older people are generally increasing globally and in LMICs in particular due to increases in life expectancy driven by epidemiological transition. For instance, the WHO estimates that by 2020, the number of people aged 60 years and older will exceed the number of children under 5 years and that by 2050, LMICs will be home to over 80% of global older people. A country like Ghana for example has one of the highest growth of the older population in sub-Saharan Africa (after South Africa) where the 60-plus cohort is projected to double from 6.0% in 2011 to approximately 12.0% in 2050.

More importantly, older populations in these countries generally face various intractable socio-economic and health-related challenges including poor access to services, decreased mobility and the occurrence of chronic conditions. Moreover, the global burden of disease reports indicates an increase in the proportion of total Disability Adjusted Life Years (DALYs) that are attributable to chronic conditions (such as diabetes, cancers and cardiovascular diseases) from 18.6–29.8% of the total burden in sub-Saharan Africa. This increase
suggests a huge shift in the disease burden from hitherto, dominant communicable diseases and childhood illnesses to a double burden of communicable and noncommunicable diseases largely due to increasing demographic aging.

In Ghana, by 2017, approximately 81% of the population had access to basic water services and only 4% used unimproved sources. However, the country has experienced slow progress in improving access to sanitation. By 2017 for example, one-half of the Ghanaian population shared sanitation facilities, a whooping 82% lacked basic sanitation, 13% used unimproved sanitation facilities, and about 18% practiced open defecation. These developments may present health and well-being challenges particularly among vulnerable groups such as older people.

The increase in the burden of chronic conditions in African countries such as Ghana is attributable to nutrition, environmental and lifestyle risk factors. Unfortunately, the role of WASH in the occurrence of chronic conditions, especially in later life is less investigated and/or poorly understood. This paper, therefore, explores the association between water and sanitation, and the occurrence of chronic conditions among older people in Ghana. It has been demonstrated that health stratification and social factors may differ by demographic circumstances. We, therefore, investigated the moderating roles of gender and residence to assess whether there are between-gender and residential heterogeneity in the association of water and sanitation with occurrence of chronic conditions among older people.

Methods

Data source

The study used data from the WHO Study on Global AGEing and adult health (SAGE). Wave 2 was a survey conducted in six LMICs, including China, Ghana, India, Mexico, Russian Federation, and South Africa. The nationally representative survey collects data through a stratified multistage cluster design to complement existing ageing data sources and inform policy and programmes. WHO and the University of Ghana Medical School through the Department of Community Health collaborated to implement SAGE Wave 2 in Ghana in 2014–2015. We used the GhanaINDDataW2 and GhanaHHDataW2 datasets. The INDD data set comprised of individual questions targeted at the main respondent and the HHD data set comprised of questions concerning the household within which the primary respondent resided.

The primary sampling units were stratified by region and location of residence (urban/rural) with samples selected from 250 enumeration areas. In households identified as “older” for sampling purposes, all household members aged 50 years and older were invited to participate in the study. Individuals were interviewed regarding their chronic health conditions and health services coverage; subjective wellbeing and quality of life; health care utilization; risk factors and preventive health behaviors; perceived health status; socio-demographic and work history; social cohesion, and household characteristics. Respondents further provided details about the use of water and sanitation facilities, including the source of water and type of toilet facility and whether these facilities were shared with others. Primary data management, checking and quality assurance was undertaken by country survey teams and coordinated centrally through WHO Geneva. The Ghana response rate was 83%. The data are publicly available via the WHO Multi-Countries Study Data Archive. Details on data and further information can be found at http://www.who.int/healthinfo/sage/cohorts/en/. Weight was calculated to offset the sampling effect.

Measures

Outcome variable

The main outcome variable of interest in this study was occurrence of chronic conditions defined as the existence of one or more chronic conditions on an individual (ranging from 1 to 8). We included all available self-reported chronic conditions queried in the WHO-SAGE data, each prompted by the item “Has a health care professional ever told you that you have... hypertension, diabetes, chronic lung diseases, angina, asthma, tightness in the chest, stroke, and arthritis?”. Individuals who indicated “yes” to these items were recorded as having a chronic condition. We dichotomized the outcome variable into 0 = no chronic condition when the respondent answers “no” to all the items and 1 = occurrence of chronic conditions when at least one response was affirmative (1-8).

Explanatory variables

Three independent variables were considered in this analysis: the source of water, type of toilet facility and shared toilet facility. First, older adults were asked to indicate the main sources of drinking water. The responses were broadly categorized into 1= piped private, 2= piped to yard/plot, 3= public tap/standpipe, 4= tube well/borehole, 5= protected dug well, 6= unprotected dug well, 7= protected spring, 8=...
unprotected spring, 9 = rainwater collection, 10 = bottled water, 11 = small scale vendor, 12 = tanker-truck/lorry, 13 = surface water (river, lake, etc.).

Based on the Joint Monitoring Program's classification of water and sanitation technologies\(^1\), we recoded these sources of water into “improved source” = 1 to include piped private, piped to yard/plot, public tap/standpipe, tube well/borehole, protected dug well, protected spring, bottled water, small scale vendor, tanker-truck/lorry, and “unimproved source” = 2 to include unprotected dug well, unprotected spring, and surface water. Type of toilet facility was collected on a 12-response scale including 1 = flush/pour to piped sewage system, 2 = flush/pour to septic tank, 3 = flush/pour to pit latrine, 4 = flush/pour to other locations, 5 = flush/pour to unknown, 6 = ventilation improved pit latrine, 7 = pit with slab, 8 = pit without slab/open, 9 = composting toilet, 10 = bucket, 11 = hanging toilet/latrine, 12 = no facilities (bush, field).

These responses were transformed into 1 = “improved toilet facility” (flush/pour to piped sewage system, flush/pour to septic tank, flush/pour to pit latrine, flush/pour to other locations, flush/pour to unknown, ventilation improved pit latrine, pit with slab, composting toilet), and 2 = “unimproved toilet facility” (pit without slab/open, bucket, hanging toilet/latrine, no facilities (bush, field). Finally, participants answered on a “no” = 1 or “yes” = 2 scale about whether toilet facility was shared with others.

**Covariates**

Sociodemographic and health-related variables were assessed and included for adjustments. These included age (years), gender (1 = male, 2 = female), location of residence (1 = urban, 2 = rural), and years of education. Marital status was collected using a four-level measure but collapsed and dichotomized into currently married/partnered = 1, and not currently married/partnered = 2. WHO-SAGE collected data on ethnic background on a 10-level scale but the variable was dichotomized into 1 = Akan, 2 = others due to the limited frequencies for specific categories and subsequent incidence of model over-fitting in the regression analysis. Respondents were asked to rate their own health, on a scale from 1 to 5 (very good, good, moderate, bad, very bad) with the item, “how would you rate your current health state?” A higher score indicated poor self-rated health and we recoded this variable into good (very good, good) = 1, moderate = 2, bad (bad/very bad) = 3 for analytic purposes.

**Statistical analysis**

Univariate descriptive analysis was first conducted to generally describe the characteristics of the sample. These statistics were reported as mean and standard deviation for continuous variables, or count and percentage for categorical variables. Next, we performed bivariate analysis stratified by gender and location of residence to estimate the relationships between the study variables using non-parametric Pearson’s \(\chi^2\) test for categorical variables and independent t-test for continuous variables. Kendall’s tau-b correlations were run to determine the relationships of relevant exposure variables with the outcome variable. Accounting for the complex survey design, survey weights were used to estimate gender- and residential-specific prevalence of chronic conditions, and water and sanitation indicators.

Given the measurement level of the outcome variable, series of hierarchical generalized logistic regression models were conducted in which the occurrence of chronic condition was regressed on the major independent variables (water, and sanitation) controlling for the potential confounders. Models 1, 2 and 3 regressed chronic condition occurrence on water source, toilet facility type and sharing of the toilet facility respectively. These crude models estimated the variance explained by the three key independent variables. In addition, chronic condition occurrence was regressed on the three key independent variables simultaneously in Model 4. Model 5 added the sociodemographic and health-related variables as controls. In Model 6, we included the interaction terms (water/sanitation indicators × gender and water/sanitation indicators × residential status) to investigate the potential modifying roles of gender and location of residence in the association of water, sanitation and chronic condition occurrence. In a confirmatory analysis, we fitted separate models to estimate the specific effect of independent variables on each individual chronic conditions. We checked for multicollinearity by computing the Variance Inflation Factor (VIF) but none of the VIF scores exceeded the value of 2.5, indicating no multicollinearity. A \(p\)-value of less than 0.05 was considered statistically significant and all analyses were performed using SPSS v.21.0 (IBM, Armonk, NY).

**Results**

**Sample characteristics**

The characteristics of the sample are presented in Table 1. Our study population consisted of 4735 adults aged 50 years or over. The average age was approximately 58 years and the majority of the respondents lived in rural areas (59%), were females (59%), and were married or partnered (57%). More than half of the respondents professed to other ethnic groups than the Akan. The mean years of education were 11 years and the health status of the sample was generally good with 68% reporting “good” and only 8% rating their health as “bad”. Approximately 19% reported at least one chronic condition. Hypertension was the most prevalent individual chronic condition (12%).
followed by arthritis (8%), tightness in the chest (4.3%), and diabetes (3%). Approximately 90% and 77% reported using improved water and toilet facility sources respectively, and 77% of the respondents shared their toilets.

**Bivariate associations**

Table 1 shows the bivariate associations stratified by gender and location of residence. Compared to females and urban dwellers, males and those in rural areas respectively were more likely to be older (p< 0.05). Similarly, males and urban residents were more likely to report higher levels of education than their respective females and rural dwellers (p< 0.001). More males were married compared with females (74% vs 45%, p< 0.001) but the majority of the married lived in rural areas compared to urban areas (61% vs 52%; p< 0.001). Males self-rated their health better compared to females and also in terms of chronic conditions (16% vs 21%; p< 0.001). Whilst the difference in health status was statistically insignificant between urban and rural residents, the former reported more co-morbidity (23% vs 16%, p< 0.001). The tendencies to use improved sources of water and toilet facilities were significantly higher for females and urban dwellers compared to male and rural dwellers respectively. Kendall’s tau-b correlations are depicted in Table 2. Co-morbidity was significantly associated with water source (τb = -0.033, p< .005), type of toilet facility (τb = -0.080, p<.001), shared toilet facility (τb = -0.044, p<.001), age (τb = 1.999, p< .001), gender (τb = 0.054, p<.001), residence (τb = -0.083, p<.001), years of education (τb = 0.046, p<.001), marital status (τb = -0.117, p< .001), and self-rated health (τb = 0.201, p< .001).

**Main regression results**

Table 3 depicts the results of the associations of water and sanitation with co-morbidity estimated by generalized logistic models of the pooled sample. In the unadjusted models (Models 1, 2, and 3), those who used unimproved water (OR= 1.350, CI: 1.037-1.757), toilet facility (OR = 1.716, CI: 1.413-2.083) and shared toilet facility (OR=1.287, 1.077-1.539) were significantly more likely to report co-morbidity. Accounting for water and sanitation variables in Model 4, the associations in Model 3 persisted but the effect sizes were negligibly attenuated by 0.12, 0.10 and 0.02 respectively. After adjusting for potential confounders (Model 5), the odds of reporting chronic condition significantly increased for those using unimproved toilet facilities (OR= 1.732, CI: 1.377-5.418), and shared toilet facilities (OR= 1.624, 1.095-2.390). However, the use of unimproved water sources lost its robustness although it had a higher odds of chronic disease risk than the use of improved water sources (OR= 1.552, 95%CI: 0.792-3.042) suggesting the potential role of sociodemographic and health-related factors in predicting co-morbidity risks in later life.

Moreover, we found significant interactions between toilet facility and gender (Model 6). Compared to males, females who used unimproved toilet facilities were 3.5 times more likely to report chronic conditions (OR= 3.498, CI: 1.744-16.442). Also, the results revealed a moderation effect of residential status on the association between water and sanitation, and co-morbidity: First, using unimproved water sources in rural areas significantly increased the risk of chronic diseases compared to living in urban areas (OR= 1.998, CI: 1.462-8.642). However, the use of unimproved water sources lost its robustness although it had a higher odds of chronic disease risk than the use of improved water sources (OR= 1.552, 95%CI: 0.792-3.042) suggesting the potential role of sociodemographic and health-related factors in predicting co-morbidity risks in later life.

**Additional models**

A sensitivity CC-specific estimations conducted showed mixed effects of water and sanitation on CCs (Table 4). The use of unimproved water and unimproved toilet facility was associated with increased likelihood of reporting hypertension, diabetes and chronic angina diseases. Moreover, the shared toilet facilities significantly increased the odds of hypertension and arthritis among older people.

**Discussion**

Chronic conditions (CCs) are highly reported public health problems for older people and continue to increase in prevalence and severity19,20. To our knowledge, this is the first study examining the association of water and sanitation with the occurrence of chronic diseases among community-dwelling older people and the first study specifically on this topic from LMICs. The findings suggest that more older people use improved water sources compared to improved sanitation facilities and that a large proportion of older people use unimproved and shared sanitation facilities. The occurrence of CCs in Ghana is generally low, with approximately 19% of older persons reporting at least one CC. Interestingly, the occurrence of CCs is higher among females and those living in rural areas as well as those using unimproved and shared sanitation facilities.

Our study highlights a less researched area on the relationship between water and sanitation and the occurrence of chronic conditions among older persons. As earlier alluded in our introduction, the public health effects of inadequate water and sanitation have always been described among children under the age of five, mainly because they are most susceptible to inadequate and poor quality services particularly in their formative years2. As humans grow older, the health challenges slowly shift focus from communicable to a double
burden of communicable and non-communicable diseases, whose occurrence especially in sub-Saharan Africa has mainly been linked to environmental, nutritional and lifestyle factors. As such, the role of water and sanitation in well-being, especially among older persons, fades away. These findings bring back the almost invisible role of water and sanitation in the health and well-being of older persons, particularly in LMICs.

Our study did not investigate the pathways through which sanitation relates to physical chronic diseases. However, in an attempt to identify the linkages and the etiology of sanitation and chronic conditions, some hypotheses are composed. Healthy aging is not only influenced by biological and psychosocial factors, but with environmental and socio-economic factors. Studies from high-income countries have highlighted that improved sanitation contributes to longevity of older persons and increases their probability of becoming centenarians. However, in many LMICs, older people increasingly face acute difficulties in accessing improved sanitation facilities. For example, due to lack of technologically appropriate sanitation facilities, older people – especially those with daily activity limitations – using pit latrines are forced to touch the walls or slabs of toilets (often times shared toilets). Such conditions may expose these vulnerable older people to sanitation-related communicable diseases. Morbidity as a result of poor environmental health conditions weaken the already existing chronic conditions among older persons and reduces their quality of life and longevity.

Notably, though, the above mentioned study by Kim & Kim was conducted in high-income countries with the certainty of having improved sanitation facilities for the majority of the population. In Ghana and most part of sub-Saharan Africa, access to sanitation facilities especially in rural areas is wanting. The country still has to make huge strides in increasing access to sanitation. It is estimated that poor sanitation costs the Ghanaian economy approximately US$290 million, and a 1.6% loss of the GDP annually. These costs are mainly felt by the poor, who are often more likely to have poor sanitation and to pay more for the effects of poor sanitation. Poverty is often linked to poor health through poor nutrition and poor access to services.

Gender and residential status were found to moderate the positive effects of unimproved sanitation use on the occurrence of chronic conditions in later life. Thus, among females and rural dwellers, exposure to unimproved sanitation was even related to more reports on chronic diseases, possibly suggesting that demographic circumstances and disparities can facilitate some degree of etiology of chronic diseases. This finding is in line with the Male-female health survival paradox, the phenomenon observed in modern human societies in which women experience greater longevity and yet higher rates of disability and poor health including chronic conditions than men. Therefore, females are more likely to report chronic conditions compared to their male counterparts in the context of using unimproved sanitation facilities. Moreover, individuals in rural areas are more likely to experience a lack of basic services and also utilize unimproved sanitation facilities compared to those in urban areas chiefly due to the lopsided nature of economic development in sub-Saharan African countries including Ghana.

The co-occurrence of chronic conditions and unimproved sanitation facilities highlights the lack of services in rural areas where older persons are more likely to live. This finding seems to support the assertion that poor communities in Ghana face a double burden of infectious and chronic diseases. These results are particularly important for older individuals, as they may be more vulnerable compared to the younger population while being at greater risk of experiencing co-morbidity and poorer health. Furthermore, the findings highlight the importance of service provision in underserved areas, especially in African countries. Using the SAGE data, for example, similarly reported that older people in areas that lack social and economic services in South Africa generally showed poor quality of life. The study further showed a decreasing gap in well-being between those with chronic conditions and those without, with an increase in resource provision. It is critical to note that the occurrence of chronic conditions among the older population is indirectly related to service provision, therefore, calling on equitable service provision across Ghana and in sub-Saharan Africa in general.

These results should be interpreted in light of several limitations. First, our measures were entirely based on retrospectively reported cross-sectional data. This prevented us from establishing temporal and thus potentially causal relationships of water and sanitation use and the occurrence of chronic conditions in later life. Our conclusions are, therefore, limited to empirical associations. We propose that further studies should attempt longitudinal analyses of these relationships. A second limitation relates to the measurement of sanitation facilities regarding the retrospective reports on the use of these facilities within the past year. A shorter time frame might have been able to detect stronger and more immediate implications of the use of the services. The self-report might have resulted in recall bias which could inundate the veracity of the findings. Despite these limitations, the current study nevertheless adds to the literature by demonstrating the moderating roles of gender and residential status against the occurrence of chronic diseases due to the use of sanitation facilities in older age.

Conclusion
Sanitation is a basic need and a responsibility that cannot be delegated or transferred to another, irrespective of one's age. This study has highlighted the indirect association between the occurrence of chronic conditions and access to improved water and sanitation services among older persons in Ghana in the context of gender and residence. The results suggest that the occurrence of chronic conditions among older people is a socio-economic proxy indicator of the lack of service provision, especially among those living in rural areas. Policy-makers and practitioners should, therefore, be aware of these implications on chronic conditions and its adverse effect on health outcomes. Whereas Ghana has made progress in increasing access to water among its population, more effort is needed in increasing access to sanitation services among older people living in rural areas. Such provision needs to be tailored with gender lenses especially in rural areas.

**Abbreviations**

CC: Chronic Conditions  
CI: Confidence interval  
DALYs: Disability Adjusted Life Years  
GDP: Gross Domestic Product  
JMP: Joint Monitoring Program  
LMICs: Low- and middle-income countries  
OR: Odds ratio  
SAGE: WHO Study on Global AGEing and adult health  
UNICEF: United Nations Children's Fund  
VIF: Variance Inflation Factor  
WASH: Water, Sanitation and Hygiene  
WHO: World Health Organization

**Declarations**

**Ethical approval**

SAGE was approved by the World Health Organization's Ethical Review Board (Reference number RPC149) and the Ethical and Protocol Review Committee, College of Health Sciences, University of Ghana, Accra, Ghana. Written informed consent was obtained from all study participants.

**Consent for publication**

Not applicable

**Availability of data and material**

The datasets used and/or analyzed during the current study are publicly available from the World Health Organization's website through the following link: http://www.who.int/healthinfo/sage/cohorts/en/

**Competing interests**

The other authors declare that they have no competing interests.

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**Authors’ contributions**

RMG, SS and MB developed the concept. RMG acquired and analysed the data. RMG, SS and MB drafted and revised the article critically for important intellectual content. All authors read and approved the final manuscript.

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Tables
Table 1. Descriptive distribution and bivariate associations of water, sanitation, demographic and health-related characteristics by gender and residential status (N = 4735)

| Potential confounders | Total | Gender | Residential status |
|-----------------------|-------|--------|-------------------|
|                       | N     | %     | N     | %     | N     | %     | N    | %     | N    | %     | Rao Scott χ² | ρ-value | Rao Scott χ² | ρ-value |
| Age (in years)        | 57.59 | ±16.74| 58.41 | ±17.19| 57.02 | ±16.39| 0.009| 56.24 | ±17.19| 58.55 | ±16.35| 0.004            |          |
| Gender                |       |       |       |       |       |       |       |       |       |       |       |                |          |
| Male                  | 1948  | (41.1)| -     | -     | -     | -     | 692  | (35.2)| 1256 | (45.3)| <0.001 |                |          |
| Female                | 2787  | (58.9)| -     | -     | -     | -     | 1273 | (64.8)| 1514 | (54.7)|        |                |          |
| Residential status    |       |       |       |       |       |       |       |       |       |       |       |                |          |
| Urban                 | 1965  | (41.5)| 692  | (35.5)| 1273 | (45.7)| <0.001| -     | -     | -     | -     |                |          |
| Rural                 | 2770  | (58.5)| 1256 | (64.5)| 1514 | (54.3)|       | -     | -     | -     | -     |                |          |
| Years of education    | 10.53 | ±5.45| 11.45 | ±5.35| 9.72  | ±5.40| <0.001| 11.43 | ±5.27| 9.64  | ±5.47| <0.001 |
| Marital relations     |       |       |       |       |       |       |       |       |       |       |       |                |          |
| Not partnered         | 2042  | (43.1)| 506  | (26.0)| 1536 | (55.1)| <0.001| 952  | (48.4)| 1090 | (39.4)| <0.001 |                |          |
| Partnered             | 2693  | (56.9)| 1442 | (74.0)| 1251 | (44.9)|       | 1013 | (51.6)| 1680 | (60.6)|        |                |          |
| Ethnicity             |       |       |       |       |       |       |       |       |       |       |       |                |          |
| Akan                  | 2296  | (48.5)| 848  | (43.5)| 1448 | (52.0)| <0.001| 1043 | (53.1)| 1253 | (45.2)| <0.001 |                |          |
| Others                | 2439  | (51.5)| 1100 | (56.5)| 1339 | (48.0)|       | 922  | (46.9)| 1517 | (54.8)|        |                |          |
| Self-rated health (SRH)|       |       |       |       |       |       |       |       |       |       |       |                |          |
| Good                  | 3192  | (68.0)| 1385 | (71.6)| 1807 | (65.4)| <0.001| 1342 | (69.2)| 1850 | (67.1)| 0.225  |                |          |
| Medium                | 1114  | (23.7)| 401  | (20.7)| 713  | (25.8)|       | 449  | (23.2)| 665  | (24.1)|        |                |          |
| Bad                   | 390   | (8.3)| 148  | (7.7)| 242  | (8.8)|       | 148  | (7.6)| 242  | (8.8)|        |                |          |
| Outcome variables     |       |       |       |       |       |       |       |       |       |       |       |                |          |
| Chronic disease       |       |       |       |       |       |       |       |       |       |       |       |                |          |
| Hypertension          | 378   | (11.8)| 114  | (8.1)| 264  | (14.8)| <0.001| 252  | (17.9)| 126  | (7.1)| <0.001 |                |          |
| Diabetes              | 99    | (3.1)| 39   | (2.8)| 60   | (3.4)| 0.322 | 67   | (4.8)| 32   | (1.8)| <0.001 |                |          |
| Chronic lung disease  | 21    | (0.4)| 10   | (0.5)| 11   | (0.4)| 0.546 | 11   | (0.6)| 10   | (0.4)| 0.303  |                |          |
| Angina                | 65    | (2.0)| 20   | (1.4)| 45   | (2.5)| 0.027 | 29   | (2.1)| 36   | (2.0)| 0.943  |                |          |
| Asthma                | 102   | (2.2)| 41   | (2.1)| 61   | (2.2)| 0.832 | 49   | (2.5)| 53   | (1.9)| 0.153  |                |          |
| Tightness in chest    | 200   | (4.3)| 79   | (4.1)| 121  | (4.4)| 0.613 | 62   | (3.2)| 138  | (5.0)| 0.003  |                |          |
| Stroke                | 55    | (1.7)| 22   | (1.6)| 33   | (1.9)| 0.521 | 31   | (2.2)| 24   | (1.3)| 0.066  |                |          |
| Arthritis | 266 (8.3) | 90 (6.4) | 176 (9.9) | <0.001 | 114 (8.1) | 152 (8.5) | 0.649 |
|-----------|------------|-----------|-----------|---------|------------|-----------|-------|

### Multimorbidity

| None          | 3847 (81.2) | 1632 (83.8) | 2215 (79.5) | <0.001 | 1521 (77.4) | 2326 (84.0) | <0.001 |
| At least one  | 888 (18.8)  | 316 (16.2)  | 572 (20.5)  | 444 (22.6) | 444 (16.0)  | 114 (8.1)   | 152 (8.5) |

### Exposure variables

#### Sources of water

| Improved       | 4260 (90.0) | 1723 (88.4) | 2537 (91.0) | 0.004 | 1900 (96.7) | 2360 (85.2) | <0.001 |
| Unimproved     | 475 (10.0)  | 225 (11.6)  | 250 (9.0)   | 65 (3.3) | 410 (14.8)  |             |       |

#### Toilet facility

| Improved       | 3646 (77.0) | 1449 (74.4) | 2197 (78.8) | <0.001 | 1805 (91.9) | 1841 (66.5) | <0.001 |
| Unimproved     | 1089 (23.0) | 499 (25.6)  | 590 (21.2)  | 160 (8.1) | 929 (33.5)  |             |       |

#### Shared toilet facility

| No            | 917 (23.3)  | 390 (24.9)  | 527 (22.3)  | 0.052 | 458 (24.4)  | 459 (22.4)  | 0.135 |
| Yes           | 3015 (76.7) | 1174 (75.1) | 1841 (77.7) | 1421 (75.6) | 1594 (77.6) |             |       |

*Mean (±SD);***p < 0.001; **p < 0.01; *p < 0.05.

### Table 2. Kendall’s tau-b correlation matrix for study variables

|           | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1. Multimorbidity | 1     |       |       |       |       |       |       |       |       |       |
| 2. Source of water | .033** |       |       |       |       |       |       |       |       |       |
| 3. Type of toilet facility | .080*** | .310*** | 1     |       |       |       |       |       |       |       |
| 4. Shared toilet facility | .044*** | .018  | .070*** | 1     |       |       |       |       |       |       |
| 5. Age      | .199*** | .003  | .021  | .086*** | 1     |       |       |       |       |       |
| 6. Gender   | .054*** | .042*** | .052*** | .031  | .045*** | 1     |       |       |       |       |
| 7. Location of residence | .083*** | .189*** | .297*** | .024  | .055*** | .101*** | 1     |       |       |       |
| 8. Years of schooling | .046*** | .057*** | .083*** | .131*** | .000  | .164*** | .183*** | 1     |       |       |
| 9. Marital status | .117*** | .093*** | .077*** | .037** | .100*** | .290*** | .091*** | .038  | 1     |       |
| 10. Ethnic background | .016  | .045*** | .189*** | .038** | .017  | .083*** | .077*** | .027  | .106*** | 1     |
| 11. Self-rated health | .201*** | .031** | .012  | .010  | .321*** | 0.061*** | .023  | .054*** | .141*** | .033** |

***p < 0.001; **p < 0.05;
Table 3. Unadjusted and adjusted (multivariate) associations of WASH with diagnosed NCDs: Generalized Logit Regression

| Variable                                      | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
|-----------------------------------------------|---------|---------|---------|---------|---------|---------|
| Source of water (ref: improved)               | OR      | OR      | OR      | OR      | OR      | OR      |
| Improved                                      | 1.350   | 1.232   | 1.552   | 1.572   |         |         |
| Unimproved                                    | (1.037-1.757)* | (1.028-1.774)* | (0.792-3.042) | (0.784-3.152) |         |         |
| Source of toilet facility (ref: improved)     | OR      | OR      | OR      | OR      | OR      | OR      |
| Improved                                      | 1.716   | 1.616   | 2.732   | 2.929   |         |         |
| Unimproved                                    | (1.413-2.083)** | (1.135-2.301)** | (1.377-5.418)** | (1.404-6.113)** |         |         |
| Shared toilet facility (ref: No)              | OR      | OR      | OR      | OR      | OR      | OR      |
| Yes                                           | 1.287   | 1.267   | 1.624   | 1.031   |         |         |
| Unimproved                                    | (1.077-1.539)*** | (1.060-1.516)** | (1.095-1.320)* | (0.799-1.329) |         |         |
| Age (in years)                                 | OR      | OR      | OR      | OR      | OR      | OR      |
| 1.052                                         |         |         |         |         |         |         |
| Sex (ref: males)                               | OR      | OR      | OR      | OR      | OR      | OR      |
| Female                                        | 1.364   | 0.767   |         |         |         |         |
| Residence (ref urban)                         | OR      | OR      | OR      | OR      | OR      | OR      |
| Rural                                         | 0.585   | 0.582   |         |         |         |         |
| Years of education                            | OR      | OR      | OR      | OR      | OR      | OR      |
| 1.018                                         |         |         |         |         |         |         |
| (0.998-1.038)                                 |         |         |         |         |         |         |
| Marital relations (ref: with no partner)      | OR      | OR      | OR      | OR      | OR      | OR      |
| With partner                                  | 0.847   | 0.849   |         |         |         |         |
| Ethnicity (ref: Akan)                         | OR      | OR      | OR      | OR      | OR      | OR      |
| Others                                        | 1.246   | 1.248   |         |         |         |         |
| (0.989-1.570)                                 |         |         |         |         |         |         |
| Self-rated health (ref: good)                 | OR      | OR      | OR      | OR      | OR      | OR      |
| Medium                                        | 1.669   | 1.677   |         |         |         |         |
| (1.276-2.183)***                             |         |         |         |         |         |         |
| Bad                                           | 2.547   | 2.543   |         |         |         |         |
| (1.732-3.747)***                             |         |         |         |         |         |         |
| Interaction terms                             | OR      | OR      | OR      | OR      | OR      | OR      |
| Source of water × gender                      | 1.185   |         |         |         |         |         |
| (0.271-5.180)                                |         |         |         |         |         |         |
| Toilet facility × gender                      | 3.498   |         |         |         |         |         |
| (1.744-16.442)**                             |         |         |         |         |         |         |

**Note:** The table includes unadjusted and adjusted (multivariate) associations of WASH with diagnosed NCDs using Generalized Logit Regression. OR stands for Odds Ratio, and 95%CI stands for 95% Confidence Interval. Significant levels are indicated as: *p < 0.05, **p < 0.01, ***p < 0.001.
OR = Odds Ratio; CI = Confidence Interval in parenthesis; NCDs = noncommunicable diseases. Models 1, 2 and 3 are unadjusted (crude) models. Model 4 included WASH variables only (sources of drinking water, toilet facility and sharing of toilet facility). Model 5 included Model 4 and adjusted for age, gender, residential status, years of education, marital status, ethnicity, and self-rated health. Model 6 included Model 5 plus interaction terms (WASH variables × gender and WASH variables × residential status).

***p < 0.001;
**p < 0.005;
*p < 0.05.
Table 4. Adjusted associations of WASH with specific diagnosed NCDs: Generalized Logit Regression

| Variable                      | Hypertension | Diabetes | Angina     | Asthma    | Tightness in chest | Stroke | Arthritis |
|-------------------------------|--------------|----------|------------|-----------|-------------------|--------|-----------|
|                               | OR (95%CI)   | OR (95%CI)| OR (95%CI) | OR (95%CI) | OR (95%CI)        | OR (95%CI) | OR (95%CI) |
| Source of water (ref: improved) | 1.901***     | 1.841**  | 1.676**    | 0.636     | 1.415             | 1.4     | 2.683     |
| Unimproved                    | (1.230-4.951)| (1.245-2.887)| (1.219-12.805)| (0.190-2.137)| (0.331-6.045)     | (0.725-4.361)| (0.627-11.468)|
| Toilet facility (ref: improved) | 2.553*       | 2.783**  | 1.724*     | 1.4       | 2.062             | 1.434   | 2.971     |
| Unimproved                    | (1.896-7.278)| (1.370-20.948)| (0.226-13.134)| (1.148-3.810)| (0.488-8.719)     | (0.188-10.943)| (0.682-12.943)|
| Shared toilet facility (ref: No) | 1.153**      | 1.327    | 0.897      | 1.250     | 0.787             | 1.008   | 1.604*    |
| Yes                           | (1.024-1.612)| (0.772-2.284)| (0.402-2.003)| (0.687-2.273)| (0.445-1.392)     | (0.463-2.195)| (1.039-2.476)|
| 2 Log likelihood              | -1146.968    | -492.591 | -309.955   | -485.392  | -551.978          | -302.868 | -691.174  |
| Nagelkerke Pseudo-R²          | 0.186        | 0.125    | 0.067      | 0.041     | 0.111             | 0.091   | 0.173     |
| Hosmer-Lemeshow               | 7.822(.451) | 5.717(.679)| 8.057(.428)| 11.988(.152)| 6.558(.585)      | 5.418(.712)| 9.198(326) |
| N                             | 4735         | 4735     | 4735       | 4735      | 4735              | 4735    | 4735      |

OR = Odds Ratio; CI = Confidence Interval; NCDs = noncommunicable diseases. All models were adjusted for age, gender, residential status, years of education, marital status, ethnicity, and self-rated health.

***p < 0.001;  
**p < 0.005; 
*p < 0.05.