Toward Sustainable Community Health Through Participatory Water and Public Health Education Programs in Southeastern Uganda

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ABSTRACT

Achieving access to safely managed water resources, sanitation and health requires multifaceted approaches in public health education programs through public-private partnerships. This study assessed the impact of public health education programs of the Center for Sustainable Rural Livelihoods and Iowa State University Uganda Program on household water access, WASH facilities, sanitation, and morbidity in Kamuli district, Uganda. We surveyed 454 households, among whom 55.1% attended public health training. Among the four public health education modules trained, 99.2, 86.8, 84.4, and 80.4 percent of households trained on WASH, sexually transmitted diseases, pregnancy health, and jigger (sand flea) and rat control, respectively. Most households (86.8%) participated in all four modules, and 74.8% attended between 9-12 rounds of training. All trainees scored at least four of six points in knowledge comprehension assessments, which has positive implications for implementation and behavioral change. In water access, overall, 87.2% had access to water from boreholes, 95.8% accessed it within two kilometers, and 62.6% spent ≤30 minutes on the round trip. In implementation, trained households (65.6%) were statistically associated with possession of at least four WASH facilities than 57.4% of non-trained. WASH facilities included latrines, bathrooms, kitchens, rubbish pits, tippy taps, and plate stands. Similarly, 57.2% of trained households were associated with possession of clean WASH facilities than 53.4% of non-trained. On morbidity, 30 days before the survey, 95.4% households reported having experienced WASH-related diseases. Overall, the poor structural and unhygienic state of WASH facilities were statistically associated with occurrences of malaria, diarrhea, and dysentery, affecting mostly non-trained households. Community education on water resources and WASH facilities should be prioritized to reduce household predisposition to related illnesses and fostering participatory monitoring of the implementation of WASH programs.

Keywords: Jiggers (sand flea), Public health education, Pregnancy health, Rat control, STDs/STIs/UTIs, WASH-related diseases.

INTRODUCTION

Water access, sanitation, hygiene, and health (WASH), wastewater collection, treatment, and proper disposal are appropriate interventions for a safe living environment.[1] The daily water demands are increasing among households and critical sectors like agriculture, industry, ecosystem, and energy.[2] In addition to efforts to increase water access, WASH interventions also go along with reducing the incidence of sanitation-related and neglected tropical diseases, which affect over one billion people, especially in developing countries.[3] Further, at the launch of the 2030 sustainable development goals (SDGs) in 2015, World Health Organization (WHO) called on stakeholders and governments for swift action to address the global burden of water access and sanitation-related diseases. This call was accompanied by a change in water access language.[4] The indicators measure water access in terms of "safely managed drinking water, and the criteria include "source should be located on the premises … be free from fecal and priority chemical contamination" (p. 13). UNICEF and WHO [5] indicated that between 2015 and 2022, there was an increase in "safely managed drinking water" from 69% to 73% globally and 27% to 31% in sub-Saharan Africa. But it was also noted that "No SDG region is on track to achieve universal access by 2030" (p. viii).[5]

On sanitation and hygiene, however, the availability of WASH facilities like latrines does not translate into improved health. For instance, the millennium development goals missed the sanitation target by 700 million people.[6] The monitoring of sanitation revealed that between 2015 and 2022, there was an increase from 49% to 57% coverage in safely managed sanitation globally and 22% to 24% in sub-Saharan Africa.[5] However, overall, 3.5 billion people did not have the facilities, and 419 million practiced open defecation. On hygiene, overall coverage increased from 67% to 75% globally, and sub-Saharan Africa had a reduction from 24% to 23% with 34%

having no facility at all in 2022, requiring further intervention in public health education. The UNICEF and WHO [5] further asserted that to achieve the SDG target by 2030, regions will require a fivefold increase in sanitation access and a threefold increase in coverage for basic hygiene facilities.

On health and morbidity, Huber et al. [7] defined health as the "ability to adapt and self-manage in the face of social, physical, and emotional challenges" (p. 235) based on the fact that chronic diseases were rising and "by successfully adapting to an illness, people are able to work …" (p. 236). Since 1990, WHO has conducted three studies on diseases to evaluate what constitutes the key indicators of human health or the relative lack of health [8] and the outcome indicator was the global burden of disease.[9] The determinants of global burden of disease, injuries, and associated risk factors are mortality, morbidity, and health of the population for eight regions of the world, disaggregated the data by age and sex. Another metric of global burden of disease was introduced, called the disability-adjusted life year, which quantifies disease burden "based on years of life lost from premature death and years of life lived in less than full health" (p. 2).[9]

The global burden of disease and disability-adjusted life year matrices have been used to assess disease occurrences for planning purposes. Naghavi et al. [10] conducted a systematic analysis of the global burden of disease between in the period, 1990–2021 in 204 countries. Results showed that WASH-related diseases, such as malaria and diarrhea, are among the leading causes of death in sub-Saharan Africa, requiring the promotion of health education interventions. Promotion of good WASH practices requires continuous public health education in communities. Architects of WASH education allude that influencing behavioral change is difficult for programs like WASH that affect the whole community.[11] However, WASH education must be tailored to communities' health needs, for

instance, by spatial distribution, urban and rural areas have different localized training needs.[11-12] Urban areas, for instance, emphasize the use of clean piped water and garbage/dust bins; rural areas use boreholes and rubbish pits. Our case study was based on the public health education programs in a Ugandan rural setting through a livelihood program founded in the United States. [13-14]

Case Study: The Center for Sustainable Rural Livelihoods (CSRL)

The CSRL program, based in the College of Agriculture and Life Sciences at Iowa State University, partners with Iowa State University Uganda Program (ISU-UP) (CSRL's implementing local organization) and Makerere University Kampala, Uganda, to implement livelihood education programs, such as WASH/public health.[13-14] The goal of WASH/public health is to influence behavioral change towards good health and food and nutrition security through construction, use, and maintenance WASH facilities such as pit latrines, kitchens, bathrooms, plate stands/dish rackers, tippy taps, rubbish pits in communities and schools. CSRL/ISU-UP identified WASH education as an appropriate intervention in contributing to the establishment of a safe living environment by reducing the incidence of WASH-related diseases such as malaria, diarrhea, and dysentery.

The CSRL/ISU-UP program adopted a comprehensive approach to human capacity development (Figure 1) with interrelated education programs that included WASH education, where they partner with the government departments of Water, Health, and Community Development; private hydrological surveyors and hand pump mechanics; and water and sanitation committees to train communities on WASH practices. These training include operations and maintenance of water resources (minor and major servicing and repairs). The water and sanitation committees, with support from program extension coordinators, also oversee the boreholes and general WASH practices in their communities and schools to create behavioral changes in the management of water resources and related diseases. In public health education, the program community-based nutrition trainers and government healthcare nurses, train community members on pregnancy health; personal hygiene-like body, hand, teeth, eye, hair, nails, foot, clothes, menstrual hygiene; jigger (sand flea) and rat controls; and several sexually transmitted diseases on synchronized monthly schedules (p. 12).[15]

Figure 1: CSRL/ISU-UP comprehensive lifespan approach to capacity development framework
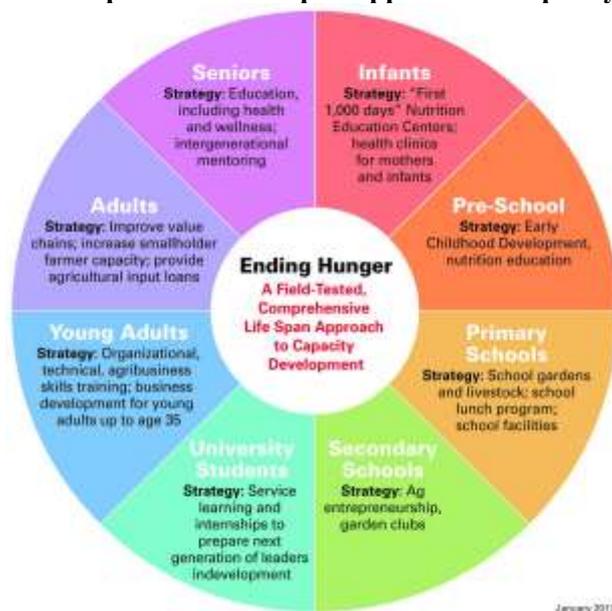
Theoretical and operational frameworks of the study

Promoting good WASH practices requires personal and community behavioral change, aligning with the theory of planned behavior [16] on which this study was founded. The theory portrays three intensions that determine human behavior, such as behavior attitude, subjective norm, and perceived behavioral control. In this study, behavioral attitude relates to how members think and feel about the health behaviors, such as personal hygiene like trimming of nails, constructing and cleaning WASH facilities like latrines.[15] Behavioral attitude has two subsets of attitude, including affective attitude describing given health behaviors, whether they are enjoyable or not; and instrumental attitude looking at various beliefs about the health behaviors being promoted, whether they are beneficial if members engage in practicing them.

The subjective norm [16] looks at the support given by members of the community with whom a member interacts with on matters relating to health behavior being promoted. In this study, the community members most importantly are the community-based nutrition and health trainers.[15] Subjective norms also have two subsets of attitudes, including injunctive norms that ask whether members in the community encourage their fellow members to participate in the health behaviors, and the descriptive norms that look at whether members in the community are also engaging in similar health behaviors and practices being promoted.

The perceived behavioral control [16] looks at personal feelings or the confidence of members being capable of engaging in health behavior that are being promoted such as constructing and maintaining the cleanliness of WASH facilities like latrines. Specifically, community members must have the capacity and positive intentions to help themselves overcome challenges that may impede their efforts to succeed in engaging in health behaviors. In our study
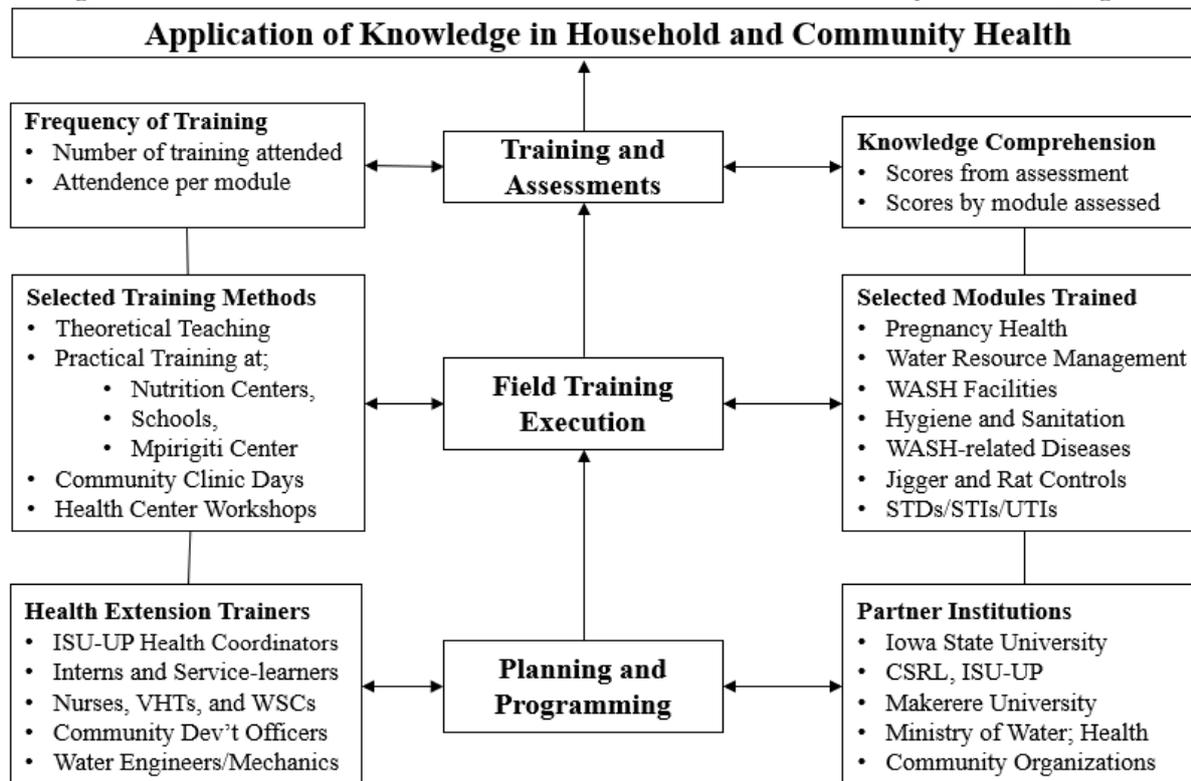
region, public health concerns include open defecation with impacts like widespread *Taenia solium,* a pork tapeworm associated with high rates of epilepsy [17], jigger/sand flea infestation with associated stigma to seek health care by the affected persons within the communities.[18]

When all three intentions in the theory of planned behavior (behavior attitude, subjective norm, and perceived behavioral control) are fulfilled, members feel strong and empowered with likelihoods of engaging in planned health behaviors.[16] This theory infuses into the WASH/public health training operations of the CSRL/ISU-UP as illustrated in the framework (Figure 2) designed for purposes of this study. The framework illustrates the phases of the training programs starting with planning and program involving both the partner institutions and their affiliated staff with various specialties in public health and related education programs. Training is executed on planned schedules (p. 12) [15], using both theory and practical methods in various places, including nutrition education centers, schools, and health centers.[15] Our study focused on a comprehensive assessment of the WASH/public health training programs

Purpose of the study

The purpose was to assess the impact of public health education programs on household access and use of WASH facilities in a comparative manner between the trained and non-trained households in Kamuli district, Uganda, for the period 2014-2018. Also, to determine the status of household predisposition to WASH-related diseases, available options for treatment of patients and/or prevention of diseases, and to offer recommendations for sustainable access and use of the WASH facilities for safe living in communities. This study was part of the impact assessment of the CSRL/ISU-UP 2014/2019 strategic plan.[14]

Figure 2: Public health education assessment framework for the study in Kamuli, Uganda

Application of Knowledge in Household and Community Health

Frequency of Training
- Number of training attended
- Attendence per module

Selected Training Methods
- Theoretical Teaching
- Practical Training at;
  - Nutrition Centers,
  - Schools,
  - Mpirigiti Center
- Community Clinic Days
- Health Center Workshops

Health Extension Trainers
- ISU-UP Health Coordinators
- Interns and Service-learners
- Nurses, VHTs, and WSCs
- Community Dev't Officers
- Water Engineers/Mechanics

Training and Assessments

Field Training Execution

Planning and Programming

Knowledge Comprehension
- Scores from assessment
- Scores by module assessed

Selected Modules Trained
- Pregnancy Health
- Water Resource Management
- WASH Facilities
- Hygiene and Sanitation
- WASH-related Diseases
- Jigger and Rat Controls
- STDs/STIs/UTIs

Partner Institutions
- Iowa State University
- CSRL, ISU-UP
- Makerere University
- Ministry of Water; Health
- Community Organizations

Abbreviations: CSRL – Center for Sustainable Rural Livelihoods, ISU-UP – Iowa State University Uganda Program, STDS/STIS/UTIs – Sexually Transmitted Diseases/Infections/Urinary Tract Infections, VHTs-Village Health Trainers, WSCs-Water and Sanitation Committees.

MATERIALS & METHODS

This study was part of a cross-sectional survey conducted in rural Kamuli district, Southeast region of Uganda (Figure 3), where the CSRL/ISU-UP implements interrelated livelihood education programs to improve household food and nutrition security. The target population was 1,503 households, who are among the clients of the nutrition education centers–rehabilitation homes for at-risk-for-malnutrition reproductive mothers and infants and children of 0–59 months of age.[15,19-20] These clients had undergone consecutive training on WASH/public health and others including agronomy, postharvest, livestock integration, nutrition and infant feeding, income innovations, and/or received services such as nutrient dense therapeutic porridge for management of malnutrition, immunization, and family planning with support from government health centers through the Ministry of Health.

We used a 95% significance level and a 5% margin of error and determined a representative sample of 306 potential participants. With the help of the program's community-based nutrition and health trainers, we accessed and interviewed 250 (81.7% access rate) households who participated in WASH/public health education programs. For purposes of comparison in this study, for every public health-trained household, we interviewed an additional non-trained household within a quarter-mile radius from a trained household. The comparative sample was 204 of non-trained households. The overall sample in the study was 454 households.

Figure 3. Study areas of Butansi and Namasagali Sub-counties in Kamuli District, Uganda.
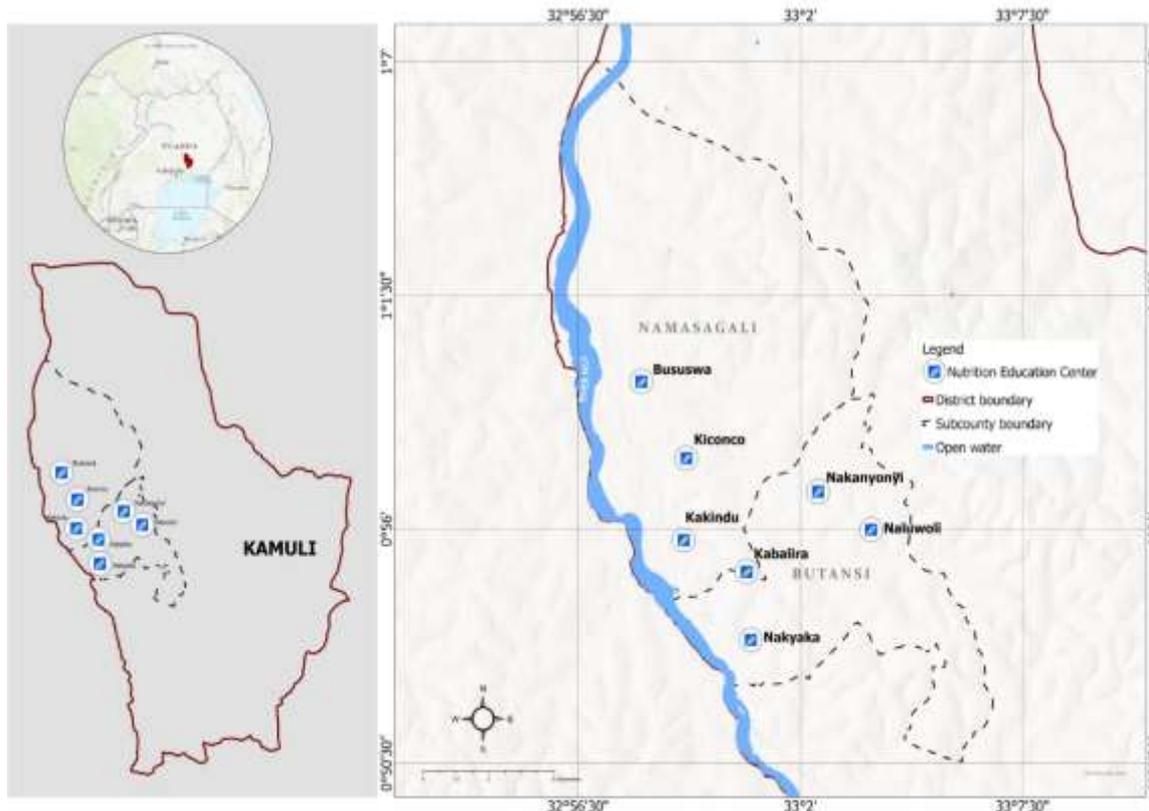
Author notes: This map was generated using GIS ArcMap tools. All the administrative layers and shape files were adopted from the Uganda Bureau of Statistics (2018).

Data collection

Data were collected on household participation in public health training, including the modules trained and the estimated number of times attended the training per module (see Figure 2). We traced four modules in this study, including WASH; jigger and rat control; pregnancy-related issues; and STDs/STIs/UTIs. We further assessed the quality of attendance with six open-ended questions to determine the level of knowledge comprehension and retention after the training. The six questions and relatively correct answers were compiled by the research team in consultation with the program trainers who conduct and oversee the implementation of the public health practices.

The study further collected data on water access, including details of the primary source of water (i.e., boreholes) and other sources. Indicators in this section included the entity that sunk the borehole, estimated distance in kilometers, and time taken in minutes for a round trip to fetch water. Also, data on the use of water from primary water sources. We also asked whether the water sources are shared with animals, and whether they stopped using any water source in the past 15 years, and the reason why they had stopped.

Also, data were collected on the availability of the six major WASH facilities, including latrines, bathrooms, kitchens, tippy taps, rubbish pits, and plate stands/dish racks, and also observed and assessed their general cleanliness. The availability and cleanliness of WASH facilities determine the predisposition to WASH-related diseases. Therefore, we also collected data on morbidity/disease, number of days of illness of patients by age and gender, and treatment/preventive options available for households on related diseases.

Data analysis

Data were entered into Excel spreadsheet, cleaned, reorganized, and exported to IBM

SPSS version 30 for analysis. Descriptive statistical analyses were done on participation in training by module, the number of times trained, and knowledge scores. An ANOVA was used to determine if there existed significant differences in knowledge assessment scores with the number of times a household member attended the training. Bivariate analyses using Chi-square (χ^2) were used to determine if there existed significant associations between trained and non-trained households on water access, availability and cleanliness of WASH facilities, morbidity, and treatment options used by households. The statistical significance was based on 5% but also used a less conservative 10% because of the high level of categorization of variables, which reduced their prediction power of the variables.[21]

Data on participation in public health training were analyzed as dummy variables with "yes" or "no" for attendance, on each of the four trained modules. We categorized attendance in the modules into three tiers: a) those below average (i.e., having trained in only 1–2 modules); b) average (i.e., trained for three modules); and c) above average (i.e., having trained in all four modules). Based on the total number of training sessions attended, we estimated the raw number of times that we were coded in three clusters.

For example, a household member whose overall attendance was less than 10 times on each of the modules was coded as "1", those between 11–20 times were coded as "2", and over 20 times were coded as "3". Thereafter, the coded numbers (i.e., 1, 2, & 3) were matched by four modules and generated a minimum of four and a maximum of twelve rounds of training for all the four modules. In the analysis and presentation, we then categorized them into three tiers, including a) fair attendance for those who attended between 1–4 training sessions, b) good for those between 5–8 training sessions, and c) very good for households with 9–12 training sessions.

On assessment of knowledge comprehension and retention, six questions were asked, for example, when should you start an antenatal clinic visit during pregnancy? And each correct response earned one point. This assessment generated a minimum of zero and a maximum of six points. Points were then categorized into three tiers, i.e., a) below average for those who scored 0–2 points, b) average for a score of 3–4 points, and c) above average for scores of 5–6 points.

On WASH, specifically, the general cleanliness, we assessed the conditions to determine the good and bad state of the facilities. WASH facilities ranked as "good state" had the following qualities on the day of interviews "well-constructed, permanent walls, a door, and were clean". WASH facilities marked as "poor state" had "temporary walls, lacked doors, were dirty, and/or non-existent". Coding was done as a dummy variable on each WASH facility availability [i.e., yes or no] and overall cleanliness [i.e., good or bad]. All data are presented in a comparative tabular form with percentages, and a chi-square statistic illustrating an association between trained, non-trained households and the overall total.

RESULT
Participation in public health training
Overall, 55.1% (*n*=250) households participated in public health education (Table 1). By module, WASH had the highest participation, while jigger and rat control had the lowest participation. Most households (86.8%) attended all four modules, a good gesture of yearning for public health knowledge. Also, 74.8% attended between 9–12 times (the maximum expected number of training). Almost all household members who participated in the training provided correct responses to the knowledge assessment and earned between 5–6 points. These results can have possible positive implications for public health practices.

Table 1: Household participation in public health education, in Kamuli, Uganda

Variable	Measures and indicators	f	%
Modules	Pregnancy health management	211	84.4
	Water, health, hygiene, and sanitation (WASH)	248	99.2
	Jigger (sand flea) and rat control	201	80.4
	Sexually transmitted diseases/infections	217	86.8
Modules trained	Above average (all four modules)	217	86.8
	Average (3 modules)	11	04.4
	Below average (1–2 modules)	22	08.8
Training attendance	Very good (9–12 training)	187	74.8
	Good (5–8 training)	41	16.4
	Fair (1–4 training)	22	08.8
Knowledge assessment questions and associated percentages to correct responses.	When should you wash your hands?	250	100
	When should you start antenatal clinic visits during pregnancy?	225	90.0
	What are the methods of preventing malaria?	250	100
	Why is it important to have a pit latrine?	250	100
	Where should you place your plates after washing?	250	100
	What are the danger signs in pregnancy?	247	98.8
Knowledge assessment	Above average (5–6 points)	250	100
	Average (3–4 points)	-	-
	Below average (0–2 points)	-	-

The number of times a household member attended training on a particular public health topic was believed to affect knowledge comprehension and application of lessons. A one-way ANOVA statistic showed that there were statistically significant differences (p=0.015) among the household members who scored in the range of 5–6 points, with the number of times they attended the training. In performing *Tukey's post hoc* analysis, it was revealed that attendees within the category 9–12 number of times trained scored higher (5.90[b]±0.30) than those who attended 1–4 times (5.68[a]±0.57). However, household members who trained 5–8 times were not any different from the two clusters (5.80[a, b]±0.51). Therefore, the more members attend health education events, the more they acquire knowledge and can rehash it when asked and may consequently practice the health behaviors trained.

Water access and use
Most households (87.2%) had access to borehole water, safe water for rural communities (Table 2). Most boreholes (54.2%) were sunk by the government, and 45.8% by other entities, including the Center for Sustainable Rural Livelihoods (CSRL) that sunk 22.7%, increasing access to clean and safe drinking water. Households (95.8%) had access to the primary water source within a two-kilometer distance, and 62.6% spent ≤30 minutes on a round trip. All households reported using it for cooking and at least 98% use water for drinking, washing, and bathing.

We found an association where trained households were 71.2% and 26.0% more likely to use water for livestock (χ^2=2.877, df=1, p=0.055) and crop irrigation (χ^2=2.186, df=1, p=0.085) as compared to 63.7% and 20.1% of the non-trained households respectively. We also established that 45.8% of households stopped using (some) water sources in the past 15 years. Among the reasons households provided were contamination, which rendered them unsafe, with 10.4% associated with trained households than 3.4% of non-trained households (χ^2=8.093, df=1, p=0.003). This association can partially be attributed to public health training on the importance of using safe sources to avert WASH-related diseases such as diarrhea.

Table 2: Household water access by percentages in Kamuli, Uganda

Variable	Indicators and measures	Not Trained (*n*=204)	Trained (*n*=250)	Total (*n*=454)	*p*-value
Primary water source	Other sources	12.7	12.8	12.8	0.551
	Borehole	87.3	87.2	87.2	
Who sunk the Borehole	Other entity	41.7	49.2	45.8	0.066
	Government	58.3	50.8	54.2	
Distance to primary water for a round trip	Greater than 2 kilometers	4.4	4.0	4.2	0.504
	Less than 2 kilometers	95.6	96.0	95.8	
Time spent collecting water for a round trip	Greater than 30 minutes	38.7	36.4	37.4	0.340
	Less than 30 minutes	61.3	63.6	62.6	
Uses of water from primary water sources	Cooking	100	100	100	-
	Drinking	100	98.8	99.3	0.166
	Bathing/washing	98.0	99.2	98.7	0.253
	Livestock operations	63.7	71.2	67.8	0.055
	Crop irrigation	20.1	26.0	23.3	0.085
Shared with animals	Yes	16.2	20.0	18.3	0.177
Stopped using water in the past 15 years	No	57.8	51.2	54.2	0.094
	Yes	42.2	48.8	45.8	
Why did you stop using some water sources	Long distance	22.5	20.0	22.2	0.489
	Water not clean	3.4	10.4	7.3	0.003
	Poor taste of water	2.9	1.2	2.0	0.162
	Got a nearby source	4.4	8.4	6.6	0.064
	Mechanical problems	2.0	1.6	1.8	0.522

Availability and cleanliness of WASH facilities

Overall, 99.1% of households possessed a WASH facility (Table 3). Trained households (65.6%) significantly possessed at least four facilities than 57.4% of non-trained households (χ^2=3.239, df=1, *p*=0.044). Similarly, trained households significantly possessed more rubbish pits, 56.4% (χ^2=7.332, df=1, *p*=0.004) and tippy taps, 48.8% (χ^2=2.634, df=1, p=0.063) than the non-trained households.

On practicing cleanliness, although only possession of "good" rubbish pits exhibited statistical significance (χ^2=10.421, df=1, *p*=0.001), trained households had more latrines, bathrooms, rubbish pits, plate stands, and tippy tap facilities in "good" clean condition than the non-trained households. This statistic is an indication of the possible implementation of lessons learned from public health education programs and campaigns.

Table 3: Percentage of WASH facilities availability and cleanliness among households

WASH facilities	Not trained (*n*=204)	Trained (*n*=250)	Total (*n*=454)	*p*-value
General availability				
Any WASH at home	**99.5**	**98.8**	**99.1**	**0.391**
Latrine	96.6	97.2	96.9	0.451
Bathrooms	83.8	82.0	82.8	0.350
Kitchens	86.8	86.0	86.7	0.462
Rubbish pits	43.6	56.4	50.7	0.004
Plate stands	31.4	37.2	34.5	0.115
Tippy taps	41.2	48.8	45.4	0.063
At least four facilities	**57.4**	**65.6**	**61.9**	**0.044**
General cleanliness				
Latrines	66.7	67.6	67.2	0.456
Bathrooms	56.9	57.6	57.3	0.475
Kitchens	66.2	60.8	63.2	0.139
Rubbish pits	26.0	40.4	33.9	0.001
Plate stands	21.1	24.8	23.1	0.205
Tippy taps	30.9	34.8	33.0	0.217
Overall cleanliness	**53.4**	**57.2**	**55.5**	**0.239**

We established associations between morbidity and the overall WASH conditions (Table 4). The poor state of overall WASH conditions predisposed households WASH-related including 49.2% diarrhea (χ^2=6.912, df=1, p=0.006); 13.5% dysentery (χ^2=3.234, df=1, p=0.009); 95.3% malaria (χ^2=3.784, df=1, p=0.037); and 66.8% Upper Respiratory disease (χ^2=4.297, df=1, p=0.024). These results imply a need for community monitoring to ensure that the learned public health knowledge is put into practice.

Morbidity occurrence, prevention, and treatment
Overall, 95.4% of households surveyed experienced disease(s) within 30 days before the survey (Table 4). Non-trained households were significantly affected with WASH-related disease like diarrhea (χ^2=2.279, df=1, p=0.079) and dysentery (χ^2=2.745, df=1, p=0.068). Among available treatments, buying of medicine (χ^2=3.318, df=1, p=0.048) and visiting the Health Centers or Village Health Trainers [VHTs] (χ^2=3.348, df=1, p=0.048) were more likely practiced by the trained households. Visiting the Health Centers and/or VHTs, are free government services and VHTs are trained, monitored by the Ministry of Health, and are linked to the Health Centers where they receive medical supplies to help the communities in which they live.[22]

All other health habits in trying to help the patients are linked to the trained households, like the use of oral rehydrated salts, especially for diarrhea, and taking patients to referral hospitals. Unfortunately, households that are not trained are associated with doing nothing for the patients, putting their lives at a higher risk and spreading the disease to other members.

Table 4: Percentage of household morbidity/disease occurrence in Kamuli, Uganda

Indicators on morbidity/disease occurrence	Not Trained	Trained	Total	*p*-value
Prevalence of diseases	*n=190*	*n=243*	*n=433*	
Diarrhea	46.3	39.1	42.3	0.079
Dysentery	12.1	7.4	9.5	0.068
Malaria	93.7	91.8	92.6	0.286
Upper respiratory – cough	62.1	60.9	61.4	0.439
Skin diseases	27.4	30.9	29.3	0.247
Prevention and treatment	*n=204*	*n=250*	*n=454*	
Buy medicines	86.8	92.0	89.6	0.048
Health Centers or Village Health Trainers	87.7	92.8	90.5	0.048
Use oral rehydrated salts	57.8	62.0	60.1	0.211
Visit Kamuli Main Hospital – Mulago	49.5	55.2	52.6	0.133
Visit Jinja Regional Referral Hospital	11.8	13.6	12.8	0.331
Use herbal medicine	19.1	16.8	17.8	0.302
Do nothing	9.3	8.4	8.8	0.429
Days of illness greater than five days	*n=204*	*n=250*	*n=454*	
Male adults	13.7	14.4	14.1	0.473
Female adults	25.0	24.4	24.7	0.484
Males 10–17 years	9.8	3.6	6.4	0.006
Females 10–17 years	9.8	9.6	9.7	0.533
Males 6–9 years	7.4	9.2	8.4	0.297
Females 6–9 years	14.2	16.0	15.2	0.347
Males under 6 years	24.0	33.2	29.1	0.020
Females under 6 years	22.1	38.0	30.8	0.001

On the days of illness, female adults of the non-trained households were more likely to be bedridden for more than five days. Significantly (χ^2=7.231, df=1, p=0.006) males between the ages of 10–17 years of non-trained households were 9.8% more likely to be bedridden for more than five days as compared to 3.6% of trained

households. Among children and infants under six years, study found that 33.2% (χ^2=4.591, df=1, *p*=0.020) and 38.0% (χ^2=13.385, df=1, *p*=0.001) of males and females, respectively, from trained households were more likely to spend more than five days when sick as compared to 24.0% and 22.1% of the non-trained households for males and females, respectively. Those children were among those undergoing malnutrition rehabilitation through nutrition programs [15,19-20] and such an association was expected.

We delved deeper into the analyses of the most common disease, malaria, in the study and found that significantly (*p*=0.057), trained households (87.3%) were likely to take their patients to Health Centers and/or VHTs for medication as compared to 81.4% of non-trained households. Similarly, trained households were 44.4% more likely to take their patients to Kamuli Main Hospital – Mulago than 36.3% of the non-trained (χ^2=3.072, df=1, *p*=0.049). Also, Jinja Referral Hospitals (regional) for malaria cases were associated (χ^2=4.208, df=1, *p*=0.031) with non-trained households (10.3%) than the trained households (5.2%). In Uganda, regional referral hospital has connotations for an advanced stage diseases that cannot be handled by local Health Centers and/or in the district-level referral hospitals. [22-23]

DISCUSSION
Participation in public health education
Public health education programs are prerequisites to behavioral change towards good health, well-being, and self-care.[24] This study showed that households were yearning for health knowledge. This call was emphasized by the Iowa State University President embedded in the letter that was sealed in 2050 time capsule appealing to the people of Kamuli district, that "… let us end hunger but let us never stop hungering for knowledge" (p. 14).[14]
The public health training modules were tailored to empower communities with health knowledge, and arose out of

consensus between program coordinators, community, and health center personnel. Education of mothers, for instance, on pregnancy health is one of the strategic approaches to achieving 70 per 100,000 live births by 2030 as stipulated in SDGs.[25] Moreover, Uganda has high rates of maternal mortality of 189 deaths and pregnancy-related mortality of 228 deaths per 100,000 live births.[26]
Expectant mothers are further at risk in rural areas faced with institutional issues like lack of enough medical supplies.[23] Maternal practices like antenatal clinic visits at least four times during pregnancy showed negative trends nationally, with reductions from 73% in 2016 to 68% in 2022.[26] These results are comparable to the findings in our study area, where 66.9% of mothers attended at least four antenatal clinic visits, and these visits reduced as the number of children born by the same mother increased and also increasing number of children born at home than in health facilities.[19] Moreover, teenage pregnancy was high with 69.3% giving birth by 19 years[19], which has health implications like underweight[27] and socio-psychological effects like pregnancy-related stigma.[28] Nevertheless, pregnancy health education programs teach mothers the best pregnancy practices like antenatal clinic visits and proper nutrition for their health, the growing fetus, and delivery of healthy babies.[29-30]
In the WASH theme, as a prerequisite for our study community to receive boreholes, members go through the water chain training and assess the availability of WASH facilities to minimize the spread of related diseases. Training is conducted by both program WASH coordinators, water and sanitation committees, government and private partners. Training equips members with an understanding of the roles and functions of their committees and how they relate to stakeholders like Village Health Trainers, school management, and local councils. The training also equips participants with practical knowledge on the operation and maintenance of water sources,

including minor and major service and repairs on water resources, knowledge on household and environmental sanitation and hygiene, gender issues about water resource management, conflict resolution, and record-keeping. Improvements in inter-agency collaborations on WASH programs will support information sharing among facilitators and practitioners [31], including special interest groups like refuges.[32]

Unfortunately, jigger control was the least attended, yet public health concern over the past decade in the study region. With low access to health education on jigger, infected communities attribute the problem to witchcraft and as family issues.[33] Also, up to 32.4% of households surveyed in Mayuge district in the study region, did not know what to do with jigger prevention. Jiggers mostly affected children between 0–5 years, especially boys.[18] An earlier study in Kenya found that some households associate jiggers with laziness, myth, and blood specific to a family [34], and in recent study, participants associated it with witchcraft.[35] These issues result in the stigmatization of affected people and shunning away from seeking help from health facilities and community health providers.[36]

Similarly, rats are also public health concerns contributing to the destruction of household property, carriage of fleas–a vector for plague disease, and destruction of harvest, increasing food insecurity in the study area. A study conducted in the West Nile region of Uganda found that within 18 months, 2,959 rats were collected with a load of 5,109 fleas.[37] Sadly, it was established that 75.5% of the rats were predominantly in-house rats carrying 85.8% of the fleas. The infectious flea species *Xenopsylla cheopis* and *X. brasiliensis* were found responsible for the long history of plague since 1920s in the Ituri district, Democratic Republic of Congo, adjacent to West Nile.[38]

Although human plague is reported to be uncommon in low elevations like West Nile of Uganda below 1,300 meters above sea level [39], Kamuli district, our study area, is at a higher elevation, over 3,600 meters above sea level, likely to experience plague invasion. This issue requires concerted effort in health education including traditional healers and formal health systems [40], and also in conjunction with postharvest education programs to manage rats and reduce postharvest losses. [41-47]

The fourth theme was STDs/STIs/UTIs, including gonorrhea, syphilis, and HIV, which are health concerns, with more than one million people acquiring infections every day globally.[48] Untreated infections are fatal, causing infertility, ectopic pregnancies, perinatal transmissions, genital sores, and a high risk of HIV transmission [49]. In Uganda, 1.5 million cases were reported between 2015 through 2017.[50] More affected were reproductive mothers (15–24 years), with an overall infection rate established at 26% from a meta-analysis of three national health surveys of 2006, 2011, and 2016.[51] Moreover, in our sample, the average age at first pregnancy was established at 18.9 years with a minimum of 12 years[19], suggesting an active sexual period with high predisposition to infections. Measures through public health education can be effective in reducing infection rates.[52-54]

Water access and use

The study established an 87.2% accessibility to borehole water, considered globally [4] and nationally [55] as safe water sources for rural communities. That proportion was higher than 77.4% established at the national average for rural communities with access to safe water.[55] The study program sunk 22.7% of the boreholes, increasing water supply and supporting government efforts in a public-private partnership.[13-14]

The distance and time taken to fetch water were reduced, easing access with 62.6% of the households spending less than 30 minutes for a round trip to fetch water and with 95.8% accessing water in less than two kilometers. Long distances were identified by the national census bureau as challenges

to accessing water, and only 70% nationally accessed water in less than a kilometer.[55] Similarly, all households use water for cooking. However, because of poor taste (2.0%) and contamination (7.3%) are some of the reasons why some households did not use the water for drinking. Contaminated borehole water has been found to have pathogenic bacteria like *Coliforms* across different regions in Uganda. [56-58] Consumption of dirty water results in death due to water-related diseases, including diarrhea, typhoid, and reduces the ability to produce human labor to contribute to food production. Also, because of water hardness, some households do not use the water for washing–it takes a lot of soap.

Efforts to achieve the sixth sustainable development goal on water quality, for instance, are on track with promising results from an analysis of borehole water for chemical composition in Uganda, Malawi, and Ethiopia.[59] Lapworth et al. [59] also emphasized a focus on microbiological compositions of the water to reduce the pathogen load that potentially cause disease and also ensure proper sinking of water wells.

Nevertheless, trained households significantly used water for livestock and crop irrigation, which increases the productivity of their farms. This association is one of the reasons why most of the trained households within this sample had livestock enterprises [60] and agronomy enterprises [45] and were both associated with being food secure [61-62] and nutritionally healthy children (<6 years).[19]

Availability and general cleanliness of WASH facilities and Morbidity
Results show that 96.9% of the households possessed latrines, the main WASH facilities, however, the 3.1% who lacked latrines were likely practicing open defecation. This percentage is lower than the national average at 9.2% for rural areas and in the Busoga region at 5.7% [our study region], who were identified to be practicing open defecation.[55] Studies conducted in

this region revealed widespread *Taenia solium*[17,63-64] and concluded that its infestation in humans was partly linked to poor disposal of human feces and consumption of infected pork, leading to epilepsy.[17] Also, poor disposal of fecal matter is among the causes of diarrhea and dysentery, significantly affecting children ≤5 five years in the region[65], in addition to a lack of handwashing stations with soap for household members to clean hands after visiting the latrines.

Similarly, the kitchen and plate stands that hold utensils, their poor state also predisposes households to diarrhea and dysentery due to flies flying between utensils and food, compromising its safety for human consumption.[12,66] Amadei (p. 435)[66] in the F-diagram describes the oral path illustrating how feces get into contact with fingers, fluids, flies, fields, and floods as primary sources; and through food, finally reach the human face as food is ingested. These scenarios require continuous public health education for behavioral changes towards healthy living, specifically the construction and maintenance of WASH facilities in good conditions.

Morbidity/disease occurrence, prevention, and treatment
There is an association between disease and poor WASH facilities. Malaria, for instance, is more linked to failure to burn or dispose of kitchen waste and other household materials placed in the rubbish pits, which then turn into breeding grounds for mosquitoes. In this study, malaria affected 92.6% households, finding similar to other studies conducted in Kamuli district.[67] A recent systematic analysis of the *global burden of disease* ranked malaria and diarrhea as the main WASH-related diseases.[5]

These diseases affected mostly children, impairing their growth with high rates of underweight and wasting within this sample[19], with implications for their safe start of the academic journey and

subsequent negative impacts in the future.[68-69] Moreover, malaria is among the main causes of stillbirth in eastern Uganda[70] and co-exists with other diseases such as HIV[71], Zika.[72] This burden requires a consolidated effort between governments and stakeholders to continue the provision of preventive items such as mosquito nets and capacity building to increase the awareness of the preventive measures, like WASH interventions.

Relatedly, diarrhea remains among the global burden responsible for high deaths, especially among children 0–59 months of age. Studies have found a positive association between precipitation and the prevalence of diarrhea.[73] In such instances where households do not possess good/clean WASH facilities, and also some practice open defecation, chances are high for households to use contaminated water, resulting in their predisposition to diarrhea.[74] A meta-analysis conducted in 12 sub-Saharan countries based on the WHO's recommended management for diarrhea found that only 52% of good management for children taken to Health Centers.[75]

Further, the analysis reported that Cote d'Ivoire in West Africa had the lowest score with 17% and there were also incidents of no care taken to help patients. This finding is equivalent to "doing nothing" for the patient, as revealed by our study with 8.8% of the households. This scenario makes patients heal by natural immunity, which is already impaired by several other illnesses; amidst the higher incidences of food insecurity [61-62,76-77] and nutrition insecurity [19,78] in the study area.

On days of illness, a statistical significance was established with more than five days of illness among children under six years, especially trained households. Mothers and their children from these households are mainly *at-risk* for malnutrition and are at the program's malnutrition rehabilitation centers.[15,19,20] However, because of food insecurity and low dietary diversity in this sample, the rate of recovery is lowered, and

at times, the relapses after rehabilitation are reported.[19] Households with children who were malnourished and food insecure had higher chances of being bedridden for more than five days, especially boys and also in the age group between 24–36 months of age. This is a weaning period with high exposure to eating contaminated food due to scavenging practices.

Studies affirm our findings that boys in the age group of 10–17 years are more likely to spend more days bedridden than girls. For instance, Byaruhanga et al. [78] found that males in elementary school were more stunted than females. Stunting caused by, among other factors, early childbirth among teen mothers [19] results in impairment of their immune system to fight diseases for a quick recovery. Proper healthcare and health education increase the survival rates of teen mothers and their infants at birth. [29-30]

CONCLUSION

Achieving access to safely managed water resources and healthcare is within our reach but requires multifaceted approaches through public-private partnerships to fosters these developments. This study assessed the long-term impact of public health education programs of the Center for Sustainable Rural Livelihoods and Iowa State University Uganda Program on household access to water, WASH facilities, hygiene, sanitation, and morbidity in Kamuli district, Uganda.

We found that 55.1% of households participated in the public health training, and the majority participated in the WASH training module. This module involved training the households and especially the Water and Sanitation Committees on operations and maintenance of water resources such as boreholes (i.e., including minor and major servicing and repairs and troubleshooting procedures) and cisterns dug alongside boreholes to collect spillage water. These committees, in turn, oversee the operation of water wells and influence behavioral changes in the communities by adopting good hygienic and sanitary

practices, including the construction and maintenance of WASH facilities like latrines, bathrooms, kitchens, tip taps, rubbish pits, and plate stands.

Influencing the communities towards behavioral change by the water committee members aligns with the theory of planned behavior.[16] Specifically the subjective norm that looks at the support given by members of the community; the injunctive norms that ask whether members in the community encourage their fellows to participate in the health behaviors; and the descriptive norms that look at whether members in the community are also engaging in those similar health behaviors and practices being promoted.

The same WASH module emphasized hygiene and sanitation at the personal level during the training, including body, hand, teeth, eye, hair, nails, foot, clothes, and during menstrual periods for mothers and their teens. Similar programs are adopted in schools through hygiene and sanitation projects implemented by a bi-national team of global service-learning students from both Makerere and Iowa State Universities, working alongside school children.[79]

Relatedly, the globally growing number of people contracting STDs/STIs/UTIs daily makes it a relevant theme in public health education for the rural communities. The effects range from infertility in both males and females, ectopic pregnancies, perinatal transmissions, genital sores, and a high risk of HIV acquisition more especially among reproductive mothers in the range of 15-24 years. It is furthermore important in such areas as rural Kamuli, where the average age at first birth was 18.94 years, with a minimum of 12 years.[19]

Preventive measures through community education can be effective in reducing the infection rates. Similarly, educating communities, especially reproductive mothers, on health issues related to pregnancy and management practices for safe childbirth contributes to contribute towards the overall Sustainable Development Goal of achieving a 70 per 100,000 live births by 2030. Such practices included an emphasis on at least four antenatal clinic visits, giving birth in health facilities with the help of trained health personnel, and obtaining proper nutrition for the healthy growth of the fetus to reduce complications at birth and overall improvements in the structural functionality of health intervention programs.[80-81]

Similarly, in the Busoga region, where Kamuli district is located, jigger infestation became a public health concern over the past decade. Regrettably, due to low access to public health education, this problem has been attributed to witchcraft and family issues. Given that some neighboring districts, like in Mayuge, some people did not know what to do with jigger prevention [33], investing in public awareness becomes a commendable practice. This education creates awareness and causes behavioral changes in household habits, lessening the stigmatization of patients in seeking help from health personnel and attending related health education programs. This issue also applies to the rats, which are destructive to stored foods and, especially, a carrier of fleas – a vector for plague. These revelations require continuous effort in public health education in conjunction with postharvest programs to reduce the effects that rats can have on human health, food and nutrition security.

In water access, overall, 87.2% had access to clean water from boreholes, with 95.8% and 62.6% accessing it within less than two kilometers and 30 minutes for a round trip, respectively. In a comparative approach to assess the impact of long-term public health education on household access and use of WASH facilities, it was established that 65.6 and 57.2 percent of trained households were associated with possession of at least four facilities and overall clean facilities, respectively. The facilities traced in this study included latrines, bathrooms, kitchens, rubbish pits, tip taps, and plate stands. The possession and cleanliness of these facilities have a direct correlation with the related diseases.

A month before the survey, overall, 95.4% of the households reported having experienced a WASH-related disease. The overall poor state of the facilities was associated with the occurrence of malaria, diarrhea, dysentery, and cough. These diseases were significantly found to affect mostly the non-trained households, further emphasizing the importance community health education programs towards WASH practices.

Diseases, specifically the related WASH, and several neglected tropical diseases thrive in filthy environments. Therefore, in addition to improving access to clean water, emphasis should be put on (re)building human capital for behavioral change on the management of water resources and WASH facilities to reduce the predisposition rate to related illnesses. Success can further be improved with public-private partnerships and good governance policies that enable non-government organizations to operate in the country. Also, strengthening the monitoring of implementation of the public health programs after community education will support assessments of the progress and devise program improvements to meet its goals.

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