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Impact of Socio-Economic Factors and Water Quality on Human Health in Rural Areas of Bufundi Sub County in Uganda: Implications for Policy and Practice

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Abstract

The study demonstrates how socio-economic factors and water quality issues have influenced human health (diarrheal and skin infections) concerns in the local communities of Bufundi sub county, south western part of Uganda. The socio-economic factors of concern included level of education, number of people in a household, incomes, water storage, water treatment and water sources. Water appearance, nitrogen compounds, and coli forms in river, spring and gravity water sources were determined. A questionnaire and laboratory analyses were applied to generate data. Results show that the chi-square values for the discriminant function between diseased and non-diseased were 30.95 and 25.48 (p=0.001) for diarrhea and skin infection respectively. Most the respondents (68.9%) obtained their water from river and spring water sources, and 77.4% never covered water drinking containers. Results show total coliforms to be 5 times higher (650 CFU/100 ml) in river water than international standards.

Keywords: Socio-economic factors; Water quality; Human health; Disease

Introduction

Wright and Boisson reported that many people (884 million) worldwide lack access to improved water resources; hundreds of millions rely on improved sources that are not consistently safe for drinking, and this is responsible for the death of more than 1.8 million people per annum due to diarrhea related diseases in developing countries [1-3]. Moreover, more than 3-quarters of Africa's drinking water come from ground water which has declined increasingly due to contaminations with microbial communities and potentially toxic substances [4,5] demonstrated that open water sources such as ponds, streams, rivers, lakes, swamps, water holes, unprotected springs and shallow wells are the typical water sources in Uganda. Studies by Ref. [6-16] have shown that poor water quality is responsible for most of the human health concerns due to waterborne diseases such as diarrhea, cholera, skin infections and several other diseases. Indicated that more than 100 species of pathogenic bacteria, viruses and protozoa can be found in contaminated water [17-21] through epidemiological evidence show that the most important risk factors to these disease infections are behaviors that encourage human contact with fecal matter including improper disposal of feces, poor sanitation practices such as open pit latrines, and lack of hand washing after defecation [22,23] and the above studies associate poor water quality and human health concerns to factors including among others the socio-economic factors such as agriculture, human settlement, general hygiene and sanitation practices, low income of households, low levels of education, and poor water storage, treatment and fetching practices.

Bufundi Sub-County is located north East of Kabale District, South Western region in Uganda (Figure 1). It is situated between latitude 01°19' South and longitude 29°52' East. It has a population of about 33,300 with about 50 functional protected spring water sources accessed by 60% of the population. The rest of the population (40%) obtains water from open water sources such as rivers, wells, and ponds.

Figure 1: Map showing study area in Uganda.

Bufundi Sub County's topography is described by steep slopes, where people construct terraces for farming. Due to these steep slopes, the area is vulnerable to natural calamities such as landslides, soil erosion and rapid loss of habitat and diversity. Water sources are communal and act for both human and animal water sources for drinking and use (Figures 2 and 3).

Figure 2: Water collection and cattle drinking point in Rutegyengyere village.

Figure 3: Destroyed gravity water source in Rutegyengyere.

According to Kabale District Planning Unit [24], during dry spells, some spring water sources dry up and cause water shortage in the area. Human settlement is on the lower areas of the hillsides near rivers and spring water areas. Water runoffs and discharges from kitchens, pit latrines and agricultural farmland flow directly into river and spring water (most especially during the rainy seasons). According to Environmental Protection Agency [25], people of the area depend on subsistence agriculture, majority live in temporary houses and the area experiences acute environmental degradation with no information on sustainable use of natural resources. In general, the area is characterized by poor settlement planning, lack of modern methods of farming, lack of defined water disinfection methods, low income generating activities, high illiteracy levels and low levels of public health concerns most especially water borne diseases. Therefore, there was a need to investigate the influence of various socio-economic factors on human health in Bufundi sub-county, and the generated information serves as baseline data for planning and environmental policy implementation.

Methods and Materials

Study area

The study was conducted from five villages in Bufundi Sub County, namely; Kacerere (KA), Rwakaroro (RW), Kashambya (KS), Kirwa (KI) and Quoters (QU). The socio-economic variables of interest include: years of education of the parent, water treatment methods, main source of water used in a household, and water storage methods. The physio-chemical and biological parameters of water for examination included: water colour and existence of organic materials (plant remains and animal materials), nitrate-nitrogen, nitrite-nitrogen, ammonium-nitrogen, fecal coli forms and total coli forms as colon forming units (CFU) per 100 ml of water samples. The research design was particularly quantitative for all the parameters of interest in this study.

Sampling design

The sample size of 100 households was chosen in the five villages and 20 households were systematically selected from houses adjacent to each other in each village. The gender for the interviewees was chosen by alternating mother and father, from one household to another in each village. A comprehensive questionnaire was administered to each selected household that included the socio-economic factors of interest. For water collection points in the communities, a total of eight sampling sites were chosen by simple random sampling as follows: 4 from the river and labelled R1, R2, R3 and R4; 3 from spring water and labelled S1, S2, and S3 and; 1 from gravity water sources labelled G1. All the sampling sites were (on average) 400 meters from each other.

Sample handling

From each sampling site, 250 ml of water samples were collected in dried bottles cleaned with boiled water. Each sample was collected at 8.00 AM in the morning, transported to the laboratory in an ice-cooled container, and was processed for analysis in triplicates within 24 hours of collection.

Reagents and instruments

All reagents used were analytical grade. All the water used for both physio-chemical and biological analysis was de-ionized water to avoid any contamination. Nitra Ver 5 nitrate and Nitri Ver 3 Nitrite reagent powder pillows were supplied by HACH Company of USA. Nessler's reagent was supplied by HACH Company Inc. A HACH DR 5000 series spectrophotometer (made by HACH Company USA) was used in the determination of concentration of nitrate-nitrogen (detection limit: 0-30.00 mgl^{-1}) and nitrite-nitrogen (detection limit LR: 0.002-0.3 mgl^{-1}). A Spectronic Helios UV-Vis Spectrophotometer series (Made in England) was used in Nesslerization.

Determination of nitrate-nitrogen

A water sample (10 ml) was added to an adapter inserted in a HACH DR 5000 series spectrophotometer programmed at wavelengths of 500 nm. Then one Nitraver 5 nitrate reagent powder pillow was added and the instrument timer started. The reaction was left to run and shake the cell at breaks of 5 minutes until an amber colour appeared that confirmed the presence of nitrates. A blank was prepared and analyzed alternately with a water sample and results read and recorded directly in mg l^{-1} of NO_3-N from the instrument into the results table.

Determination of ammonium-nitrogen

To 5 ml of the diluted and filtered sample in a clean test tube, 0.2 ml of Nessler reagent were added and the mixture was shaken. The absorbance of the samples was measured using a Helios UV-Vis Scanning Spectrophotometer (detection limit 20 µg l^{-1}) at 425 nm after 15 minutes against the blank sample. Ammonium-nitrogen concentrations were obtained directly from the calibration curve and recorded.

Enumeration of coliforms

To each sample, 50 ml of water was filtered and the number of coli forms counted. At first, the samples were incubated at 35°C for 24 hours on endo type medium containing lactose and the red colonies with a metallic sheen that appeared were counted and recorded as total coliforms. To enumerate fecal coliforms, the filters were incubated on an enriched lactose medium (mFC) at a temperature of 44.5°C for 24 hours, and the blue colonies that appeared were counted as fecal coliforms. All counts were expressed as either total or fecal coliforms per 100 ml of water. All water samples having one or more coliforms per 100 ml were judged to be poor quality, based on zero tolerance level for coliforms in drinking water [26].

Data analysis

The coded data was analyzed using Microsoft Access and discriminant analysis (DA) in SPSS [27] for easy determination of which variables discriminate between the diseased and non-diseased groups of both diarrhea and skin infection. Variables considered under this analysis were: years of education, age of the parent, number of children less than five years per household and total number of people in each household. Descriptive statistics analysis was also used to determine how responses are distributed over the range of possible options for water sources, water storage, water appearance and water treatment. These variables were analyzed using SPSS and the results are reported with numbers and percentages for each response category. To determine the safe levels for drinking water, the chemical water quality indicators (NO_3-N, NO_2-N and NH_4-N) and biological (fecal and total coliforms) water quality indicators were compared with national and international guidelines.

Results and Discussion

Socio-economic factors

The results of the analysis model indicate that years of education of the parent and the total number of people per household are the best predictors of whether the household is likely to have a child below 5 years with diarrhea or not and skin infection or not due to their high classification coefficients indicated in (Equations 1 and 2).

Equation 1: Shows Fisher's coefficients to predict disease cases of diarrhea.

Diarrhea=-78.449+2.156*Age_parent+4.541*No_pple +4.941*Years_edu+0.692*No chdn_5

No disease =-72.086+2.062*Age_parent+3.968*No_pple +4.910*Years_educ+0.880*Nochdn_5

Equation 2: Shows Fisher's coefficients to predict disease cases of skin infections

Skin infection=-76.609+2.051*Age_parent+4.825*No_pple +4.902*Years_edu+.484*No chdn_5

No infections=-70.708+1.994*Age_parent+4.144*No_pple +4.826*Years_educ+0.696*No chdn_5

The calculated Wilky's Lambda statistical value ($p=0.001<0.05$) suggests a rejection of the null hypothesis and shows that the model differentiates scores among groups (diseased and non-diseased) significantly (Table 1).

HO: The two groups have the same mean discriminant function scores; $\mu1=\mu2$

HA: The two groups have unequal mean discriminant function scores; $\mu1\neq\mu2$

From the Table 1 below, (0.615)2 gives 0.378, which means that the model explains 37.8% of variance in the grouping variable (diarrhea disease or no disease) for diarrhea cases. Thus, 615 indicates a moderate correlation between the discriminant scores of diarrheas diseased and non-diseased (Table 2).

Functions	Wilks' Lambda	Chi-square	Canonical Correlation	Sig.
Diarrhea disease	0.621	30.946	0.615	0.001
Skin infection	0.667	25.484	0.577	0.001

Table 1: Wilk's Lambda for disease groups.

Variable	Diarrhea in under fives		Skin infection in under fives	
	1-Diarrhea	2-No disease	1-Infection	2-No infection
Age of the parent	2.156	2.062	2.051	1.994
No. of people/household	4.541	3.968	4.825	4.144
Years of education of the pa	4.941	4.910	4.902	4.826
No. of children under five	0.692	0.880	0.484	0.696
(Constant)	-78.449	-72.086	-76.609	-70.708

Table 2: Classification function coefficients for diarrhea and skin infection cases.

The Wilk's lambda value in the table provides proportion of the total variability not explained by the model. Results from this analysis (Table 3) show that 62.1% of the total variance in the discriminant scores is not explained by the differences among the groups. The Chi-square, 30.946 is significant ($p=0.001<0.05$) at 95% level of confidence indicating that the group means differ for diarrhea case.

Variable	Diarrhea		Skin Infection	
	Wilks' Lambda	Sig.	Wilks' Lambda	Sig.
Age of the parent	0.667	0.001	0.732	0.001
No. of people/household	0.645	0.001	0.679	0.001
Years of education	0.702	0.001	0.756	0.001
No. of children under five	0.937	0.037	0.940	0.046

Table 3: Equality of group means for diarrhea and skin infection cases.

The study also found out that children with aged parents /guardians were at a high risk of suffering from the diseases compared to those with young parents/guardian. The study also revealed that the number of children under the age of five in a household is less significant in exposing young children to risks of diarrhea and skin infection (p=0.037 and p=0.46 respectively), compared to the age of the parent, number of people per household and level of education of the parent (p=0.001) (Table 3).

Table 4 below shows that most of the population (62.5%) use water from rivers or springs while others harvest and store rain water (7.5%), have installed ordinary containers (5%) and those that don't have any category of water storage were 3.8%. Most of the respondents (68.9%) believe that water used is of low quality due its appearance, presence of suspended particles and small organisms like worms. The most common method of water treatment known in the areas is water boiling (100%) and the majority of the population (77.4%) store boiled drinking water in closed containers like small neck bottles and jugs. Only a small number (20.8%) use open water containers like buckets and pans to keep their boiled water for drinking.

Water Sources	Freq	% age	Quality awareness	Freq	% age	Treatment and storage	Freq	% Age
Water tank	6	7.5	Dirty/cloudy	51	68.9	Boiling	64	100
Drum/bucket	4	5.0	Small organisms/worms	17	23.0	Missing	37	
Rain	3	3.8	Chemical contamination	3	4.1	Open container	72	77.4
River/spring	50	62.5	Bad smell/taste	2	2.7	Closed container	21	22.6
Well	13	16.3	Not sure	1	1.4	Missing	8	-
Not sure	4	5.0	-	-	-	-	-	-

Table 4: Frequency distribution of water source, storage and treatment.

Chemical factors

Findings from this study show that there was high ammonium-nitrogen in river water compared to spring and gravity water sources (Table 5 and Figure 5). These high concentrations of ammonium-nitrogen in water samples are attributed to discharges from kitchen, local brewing areas, rotting surface vegetation and animal wastes from grazing areas. A very low concentration of nitrite-nitrogen is recorded at only one spot of spring water relative to the rest of the water sources (Table 5 and Figure 4). Results also indicate spring and gravity water to have relatively high concentrations of nitrate-nitrogen. However, the nitrogenous compound values observed at all sites are below both national and international guidelines of 10 mg/ml for each parameter considered hence there was low level of water pollution by nitrogen nutrients.

Sample ID	NH_4-N (mgl^{-1})	NO_2-N (mgl^{-1})	NO_3-N (mgl^{-1})	Coliforms (CFU/100 ml)	
				Fecal coliforms	Total coliforms
R1	0.423	0.004	0.309	0.000	13.000
R2	0.294	0.017	0.112	0.000	170.000
R3	0.248	0.021	0.209	0.000	430.000
R4	0.271	0.021	0.078	0.000	650.000
S1	0.241	0.000	0.223	0.000	9.000
S2	0.166	0.004	1.367	0.000	0.000
S3	0.218	0.000	1.735	0.000	0.000
G1	0.121	0.000	0.394	0.000	0.000
National guidelines	N/A	3.000	50.000	50.000	100.000

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International guidelines	N/A	1.000	10.000	0.000	0.000

Table 5: Average chemical and microbiological water composition.

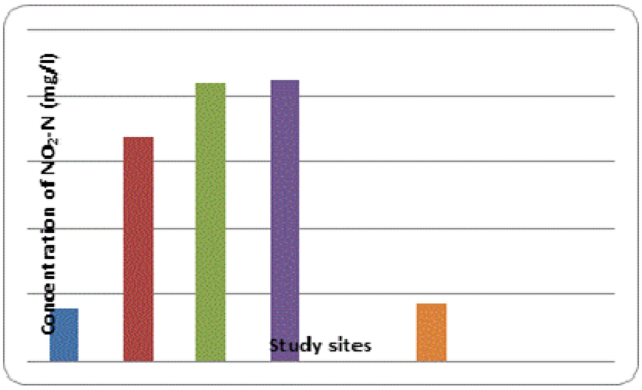

Figure 4: Variation of nitrite-nitrogen at various study sites.

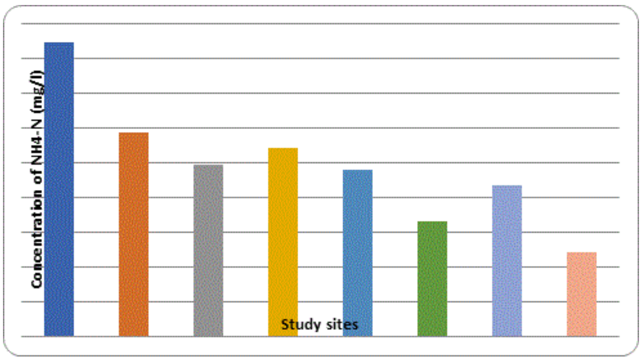

Figure 5: Variation of ammonium-nitrogen at various study sites.

Biological factors

The concentration of fecal coliforms was 0 CFU/100 ml of water sample in all the water samples from the river, spring and gravity water (Table 5 and Figure 6). However, there were high counts of total coliforms detected in river samples compared to spring and gravity water samples. The absence of fecal coliforms in water samples indicated that water was free from fecal material at the time of sampling. Sampling stations R_4, R_3 and R_2 have high total coliforms of 650 (which is more than 6 times the recommended level in the national guidelines), 430 and 170 CFU/ 100 ml respectively. Results show that sampling station S1 was the only spring water study site that registered total coliforms (9 CFU/100 ml) probably due to its location in a valley surrounded by homesteads on gentle slopes of hills. Gravity water sample indicated no contamination with total coliforms per 100 ml of water sample. The presence of total coliforms other than fecal coliforms to some sources of water is associated with environmental sources rather than fecal materials from human beings. This agrees with findings by Ref. [28] who demonstrates that total coliform bacteria are common in the environment like soil or vegetation, and are generally harmless.

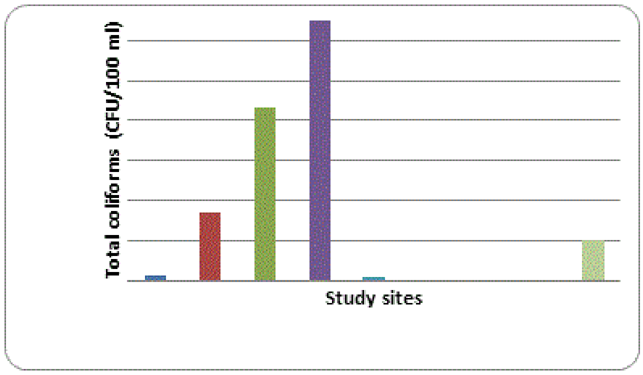

Figure 6: Variation of total coliforms at different study sites.

Conclusion

From the results, the level of education and number of children under the age of five in a household are better predictors of diarrhea and skin infection in Bufundi Sub county (Tables 2 and 3). This is also supported by the calculated Fischer's coefficients as shown in equations 1 and 2, and Table 2. In addition, the study found out that children with aged parents/guardians were at more risk of suffering from the diseases compared to those with young parents/guardians. All the water sources show low pollution levels as observed from results (Table 5) by comparing with international guidelines-10 mg.l-1 [29] of nitrate-nitrogen. However, the study shows that consumption of untreated river water is riskier than consumption of spring and gravity water (Table 5 and Figure 6). There are high levels of total coliforms in water sources especially river waters but no fecal coliforms observed at any source. The high levels of total coliforms are attributed to environmental sources rather than human fecal materials. The most common method of water treatment in rural areas in Uganda is boiling water for drinking. However, this method is inefficient in removing toxic substances or chemicals. Boiling water only kills some microorganisms but has no impact on other toxic substances. Studies by Ref. [30,31] have associated use of water of poor quality to the transmission of infectious diseases such as diarrhea, cholera and skin diseases in the tropics. There is need to conduct environmental health education and promote appropriate family planning methods in Bufundi sub county to reduce the risk of exposure to environmental related diseases.

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