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ASSESSMENT OF DRINKING WATER QUALITY FROM THE INFORMAL WATER VENDORS AT KULGUDURI IN NALERIGU.

Authors

[1]Mahama Bashiru, [2]Prince Antwi-Agyei, [3]Christopher Doku, [4]Peter Awudu N, [5]Yendoh Justin J.

[1,5] Department of Water and Sanitation, College Of Nursing and Midwifery, Post Office Box 10, Nalerigu-NE/R, Ghana

[2]Regional Centre for Energy and Environmental Sustainability-University of Energy and Natural Resources, Ghana

[3]Works Department- Assin South District Assembly, Central Region, Ghana

[4]Department of Allied Health, College Of Nursing and Midwifery, Post Office Box 10, Nalerigu-NE/R, Ghana

Corresponding author: Mahama Bashiru

Mail:bashirumahama1@gmail.com

CONTACT: 0249743642/0207167815

ASSESSMENT OF DRINKING WATER QUALITY FROM THE INFORMAL WATER VENDORS AT KULGUDURI IN NALERIGU.

ABSTRACT

The study was conducted at Kulguduri in Nalerigu, the North East Region of Ghana to assess water quality from the informal water vendors. Limited supply of municipal water in most developing areas has resulted in the use of alternative water supply means known as water vending. Water vendor activities such as; water collection, handling and transportation interfere with the quality of water. A quantitative design (i.e. testing for water quality parameters) was used for the study. A total of eighteen (18) water samples were collected, these included three (3) samples each from three different hand-dug wells, six (6) samples from informal water vendors and three (3) samples from household consumption point. The study revealed physico-chemical parameters of water source, vendor's water and household distribution points had mean pH values of 5.79, 5.59 and 5.56 indicating a significant reduction in pH ($p=0.00$). Also, microbiological risk assessment (QMRA) assessment revealed high risk of infection from source water and vended water. *E.coli* contamination from water source and vended water were not significantly different ($p=0.11$) and were above WHO acceptable limit of risk to consumption from pathogens (10^{-5}) daily per individual per annum. This showed a high risk of getting infections from consuming water from both source and vended water. The study findings will be useful to stakeholders and MMDA's for planning and decision making in water for public health benefits and economic growth.

Keywords; Water Quality, Pollution, Drinking Water, Vendors and Attributes, Risk assessment.

Introduction

Water is good for human development, and therefore, adequate, safe and regular supply is a concern. The sustainable and proper management of water and sanitation is essential for everyone in the accomplishment of the sustainable development goal (SDG 6) for water (UNICEF & WHO, 2019). It is worth to suggest that; the availability of water and its access and supply are unequally across the world populations (Ashaiman & Morinville, 2014). The SDG 6 is to secure a comprehensive and easy accessibility to safe and portable drinking water supplies. The target is tracked with "how drinking water supplies and distribution are adequately managed to ensure good water quality", access with easily available means of getting drinking water that is contaminants free (UNICEF & WHO, 2019). In many African countries, safe drinking water with supply is a major concern including Ghana. The most pressing issues are irregular provision and supply of safe drinking water (Afriyie & Ferber, 2018). In Ghana, 8.3 million of the inhabitants gain little or no accessibility to safe water service, while 23.1 million (73%) of the entire people do not get safe and properly managed water services that provide households with clean and safe drinking water (Afriyie & Ferber, 2018). The disparities in supply, distribution and means of getting safe water is a predicament to most populations in Ghana especially, in the rural areas (Afriyie & Ferber, 2018). About 800,000 of the inhabitants in the Northern part of Ghana for instance, consume water from sources that are insufficient in quality and remain a public health threat (Afriyie & Ferber, 2018; WaterAid, 2016). Increase in human population, urbanization, industrialization, use of agrochemicals (e.g. pesticides and fertilizers) and anthropogenic activities have influenced the quality of water in many cases. The North East Region has limited access to drinking water with the majority of the population getting water for domestic activities through different sources such as rivers and open wells that are contaminated with waterborne pathogens (Ghana Statistical Service, 2010). The limited supply and inadequate coverage of municipal water systems in most areas have therefore called for alternative ways for water supply and distribution. Regardless of the enormous benefits of the informal water vendor, vending of water poses a significant threat to water quality due to contamination. Although many researches have been done in other jurisdictions to investigate the water quality from the informal water vendors, no similar or same study has been conducted in Kulguduri. Therefore, the rationale for the study was to investigate water quality from the informal water vendors, which include; water tanker, tricycles, donkey carts is crucial to public health.

MATERIALS AND METHODS

Study Area

The area for the study was kulguduri, a suburb of Nalerigu, the capital town of the North East Region. Nalerigu is one of the newly created regions in Ghana and bounded to south is Northern Region, and to the North is the Upper East region. Majority (85%) of the people are involved in agriculture with the remaining being traders and others. About (96.0%) of the population in Kulguduri in Nalerigu in East Mamprusi district are unemployed (Ghana Statistical Service & Ghana Demographic Health Survery, 2008). Very low proportions of the population are employed in the public sector: government (2%), private formal (1%) and NGOs at local and international (1%). The main sources of water for the inhabitants' are; borehole and tube well (33.6%) and river and streams (28.8%). Pipe borne water is also used by a relatively high proportion of urban households (30.1%) compared to rural households (1.1%) (Ghana Statistical Service & Ghana Demographic Health Survery, 2008).

Study Design

The design for the study was quantitative (testing for water quality parameters).

Sample Collection, Storage, and Transportation

Eighteen (18) water samples were collected for the study. These included nine (9) samples taken from three different hand-dug wells namely; Mongo-well, Bismillahi-well and the Kpariboa-well. Three (3) samples were taken from each source water for laboratory analysis. Also, six (6) samples were collected from the informal water vendors (i.e. donkey cart, water tanker, and tricycle services) at the same collection time with samples from source water for the study. Also, three (3) samples were taken from household consumption point. All laboratory analysis relied on the eighteen samples for the physicochemical (i.e. pH, turbidity, alkalinity, total dissolve solids, phosphates and nitrates) and microbiological parameters (i.e. *E.coli*) for the study. Sample collection for the study considered the WHO guidelines for water (World Health Organization, 2014). Samples were collected with clean bottles of at least 1.5-liter capacity. The samples were taken to the laboratory between 5 to 6 hours for analysis. Sample bottles were fitted with a round-glass stopper, or a polythene-lined plastic stopper, and were rinsed out before they were (APHA et al., 2005).

Laboratory Analysis of Physico-Chemical Parameters

Analytical water quality characteristics with their analytical techniques such as titrimetric, colorimetric, and modified wrinkle bottle method were used for the study. The following characteristics were analyzed using analytical techniques including; thermometer, turbidimeter and pH meter for temperature, turbidity and pH determination of collected samples (APHA et al., 2005). Water samples for pH of the various sources were gently shaken to mix well, and the aliquots were placed in beakers well labelled. The pH of the water sources were then measured by immersing the pH electrode into the water samples in the various beakers depicting their sources. pH of samples were allowed to stabilize, and their values recorded (APHA et al., 2005; Environment, 1999).

Laboratory Analysis of Microbiological Parameters

Faecal bacteria may poses a considerable health risk to water consumers (Odonkor & Ampofo, 2013). Indicator microorganisms in drinking water are mostly bacteria, and are practically used to analyse microbiological quality of water. Among such indicators organisms, the most commonly ones are thermotolerant (fecal) coliforms or E.coli (Shukla & Jain, 2017). Presently, E. coli is the best predictor of the presence of feces in water (Odonkor & Ampofo, 2013). Escherichia coli, and total coliforms were determined for this study with the aid of a chromo cult broth media (APHA et al., 2005). A multiple-tube method was used for the microbiological parameters analysis. In this procedure, many tubes with the correct selective broth culture were used. Gas formation in the inoculated samples indicated the possible presence of coliforms. The bacteria present were then estimated from the inoculated tubes using statistical tables (Clark, 2015).

Quantitative microbial risk assessment (QMRA)

Quantitative Microbial risk assessment (QMRA) was conducted to predict the possible effect of illness due to contact with pathogens through source water. The risk assessment method is use to predict the impact of illness from ingestion or contact with pathogens (Howard et al., 2006). QMRA has different phases such as; assessment of exposure, dose-response calculation and risk characterization. E. coli is considered predictive bacteria and was used to predict the risk of daily and yearly infection to pathogenic microorganisms (Howard et al., 2006).

Hazard identification and characterization

This involves the selection of waterborne pathogens within the system that has the potential to cause human hazard and the identification of possible transmission and exposure means (Medema, 2015). Hazard identification is based on pathogens and the impact they have on drinking water and humans (Medema, 2013; USEPA, 2014). Pathogenic traces of *E. coli* is a critical predicament for public health (Howard et al., 2006). The most predominantly used reference pathogens include Salmonella, *E. coli* O57:H7, Cryptosporidium, rotavirus and Campylobacter (Medema, 2013; Kent, *et al.*, 2016). The quantity of microbial pathogens that are ingested with respect to time of exposure for a given pathway can be calculated using the equation:

$$D = C \times \frac{1}{R} \times V \qquad Equation\ (1)$$

Where D is the quantum of ingested pathogens with respect to time, C is the pathogen concentration in the water consumed, R is the recovery efficiency of the pathogen, and V is the volume of water consumed per occasion.

Exposure assessment

This is the process of determining quantitatively the magnitude and frequency of the reference microorganism or pathogen identified in the hazard identification phase. This stage defines the sources of the reference pathogens, exposure routes and pathways as well (USEPA, 2014). The potential exposure routes are key to establish microbial impact on health as most consume water from these sources. In exposure assessment, the concentration of microbial pathogens is estimated. The estimation may contain the real level of pathogens or the probability of its occurrence derived from the data in a specified probability distribution. Therefore, exposure assessment describes the concentrations of microorganisms in a given water source without affecting the volumes consumed or ingested by the exposed population (USEPA, 2014). The size and nature of the exposed persons, the means of exposure, frequency, duration and the magnitude of exposure associated with the exposure routes are evaluated (Sunger & Haas, 2015).

Dose-response assessment

The dose impact investigation is predictive of the health outcomes linked with the contact to pathogens in water. The dose-response model is used to analyze the number of pathogens ingested and the likelihood of illness occurring (Sunger and Haas, 2015; WHO, 2016). Even though, the dose-response models have been used in previous work using strains of microbial pathogens (Medama, 2013; Westrell et al., 2004). The information regarding the effects of pathogen and hosts immunity is still unclear (Eregno et al., 2013). The likelihood of a negative impact of the contact with pathogens is calculated using the dose-response model (WHO, 2016). The distribution of microbial pathogens in water is considered as a poison distribution and has a dose-response equation as exponential (Equation 2). However, a heterogeneous in the likelihood of microbial pathogens and the probability among these pathogens and the hosts are beta distributions that lead to the β-Poisson distribution (Equation 3). The dose-response relationship is applicable to certain pathogens, but the pathogen estimated in the source water may be insufficient.

$$P1 = \mathrm{e}^{-\mathrm{e}-\mathrm{r}\mathrm{D}} \qquad Equation\ (2)$$

$$P1 = 1\text{-}\left(1 + \frac{D}{\beta}\right)\text{-}\alpha \qquad Equation\ (3)$$

Where PI is the likelihood of infection, D is ingested pathogens, and α, β are the beta distribution parameters.

Risk characterization

This phase integrates all the information on QMRA; it includes the anticipated impact of the consumed dose, estimation of the risk, the variance and unreliability in the estimated risk, and sensitivity analysis. The risk characterization is conducted by either deterministic or stochastic estimate ways. The deterministic estimate of risk is when the exposure number of organisms ingested or consumed adds up with a point estimate of the dose-response parameters to estimate the rate of illness.

To estimate the risk, Monte Carlo sampling approaches are adopted (Palisade Corporation, 2012). The risk characterization estimates annual infection probability (P) through exposure outcomes (Sunger & Haas, 2015).

$$P1\,(d) = 1 - \left[1 + \left(\frac{d}{N50}\right)\left(2\frac{1}{\alpha} - 1\right)\right] - \alpha \qquad Equation\ (4)$$

Where P is the annual likelihood of infection, d is ingested pathogens, N is the pathogen concentration, N50 is the microbial dose of exposed population; α is the pathogen infective constant (Haas et. al., 1999).

Data Analysis

Analysis of variance (ANOVA) method was used for data analysis and results were presented on tables for both the physico-chemical and microbiological characteristics. Statistical tests were estimated at 5% level of significance (p=0.05). A quantitative microbial risk assessment was carried out using @Risk software for risk characterization (Medema, 2013) . The exposure paths to pathogenic microorganisms were established in order to estimate the risk of infection to human by using E. coli as a reference pathogen for the QMRA.

RESULTS AND DISCUSSIONS

Physicochemical Characteristics at Source Water, Vendor's Water and Household Distribution Point

The descriptive statistics of the physicochemical characteristics at source water, vendor's water and household distribution point are presented in Table 1. pH determines the solubility of chemical and biological constituents in water (Ibrahim et al., 2020). Findings revealed that, the mean pH values at the source water, vendor's water and the distribution point were 5.79, 5.59 and 5.56. Comparatively, the pH reduced from source water to household distribution point but was below the WHO guidelines for pH (6.5-8.5). The mean pH values were significantly different among the source water, vendor's water and household distribution point (p=0.00). The variation in the mean values for pH could be predictive of the status of pollution from source water as well as the influence of vendor activities during the transportation and distribution of water to households. WHO indicated that, water is considered drinkable when it contains nitrate components up to 10 mg/l. Nitrate reduces within the human body to nitrite, which could result in methemoglobinemia or blue baby syndrome (Skipton, 2013; WHO, 2016) . The mean nitrate values for the source water, vendor's water and the household distribution point were 14.94, 15.58 and 15.8. The study further revealed that; nitrate components in the source water, vended water and household distribution point were not within the WHO recommended standards. The slightly increased in the mean nitrates values may be influenced by domestic activities such; type of storage containers and how water is exposed to other factors in the homes. This showed mean nitrate values were significantly different among source water, vendor's water and household distribution point (p=0.00). The study findings also indicated turbidity level reduced from the water source through to the distribution (34, 31.3 and 24.17). The decreased in turbidity may as well be influenced by household water handling activities such as measures used for treatment and storage of water. The permissible level for turbidity is ≤5 NTU, since consumers judge the quality of water simply from its appearance (WHO, 2016; World Health

Organization & UNICEF, 2017). The study showed mean turbidity values were significantly different among the source water, vendor's water and household distribution (p=0.01). The mean phosphate values in the current study were not significantly different among source water, vendor's water and household distribution point in table 1.

Table 1: Descriptive Analysis of Physicochemical Parameters at Source Water, Vendor's Water and Household Distribution Point.

Parameter	Source water		Vended water		Distribution point		p-values	WHO guideline
	Mean ± St.D.	Min-Max	Mean ± St.D	Min-Max	Mean ± St.D	Min-Max		
pH	5.79±0.82	5.2-6.72	5.59±0.44	5.28-5.59	5.56±0.38	5.28-6.00	0.000	**6.5-8.5**
Turbidity (NTU)	34±6.93	30-42	31.3±5.05	25.50-34.50	24.17±1.26	23-25.50	0.010	**≤5**
Alkalinity	30.20±2.52	27.50-32.50	36.3±5.39	32.50-42.50	32.37±1.47	31.12-34	0.003	**-**
TDS (mg/l)	18.20±15.54	7.50-36	18.8±16.65	8-38	18±15.62	8-36	0.000	**1000**
Phosphate (mg/l)	0.35±0.001	0.3-0.4	0.05±0.02	0.03-0.07	0.05±0.03	0.02-0.07	0.272	**<1**
Nitrates (mg/l)	**14.94±4.70**	**10.20-19.61**	**15.58±2.94**	**14.15-19.28**	**15.8±2.94**	**14.15-19.28**	**0.000**	**10**

Microbial Characteristics of Drinking Source Water

Microbial contamination in drinking water can result into water associated diseases (WHO, 2016; World Health Organization & UNICEF, 2017). WHO indicated that; 0 detected E. coli concentration in 100 ml of drinking water is permissible for human consumption (WHO, 2016). Microbial contamination by animals and human feces is the primary reason for the contamination of water and therefore not safer for consumption (Muazu et al., 2012). The microbiological characteristics of water may include the presence of microorganisms of various forms and the effect they may pose to humans (Pal et al., 2018). The study revealed detected E.coli strains in the source water and vended water. The levels of contamination of E.coli from source water and vended water were insignificant (p=0.11) as shown in Table 2. The sources of water may impact negatively on the wellbeing of humans that include; concerns for microbial contaminants, coupled with unknown source of vended water, inadequately monitored, and storage in unhygienic conditions (Afriyie & Ferber, 2018; Ahlers et al., 2014; Bain, Cronk, Hossain, et al., 2014; Bain, Cronk, Wright, et al., 2014; *For Water Statistics*, n.d.). The existence of E.coli in water indicates a possible disease causing microorganism otherwise pathogens that pose a public health threat to consumers (Kent. et al., 2016). A previous literature indicated poor sanitation, hygiene and household water handling practices could influence higher levels of E.coli in water (Gwimbi, 2011).

Table 2: Mean E.coli Count (MPN /100ml) of Source Water and Vended Water.

Source water	***Mean E. coli* count (MPN/100ml)**	**Vendor Source**	***Mean E.coli count (MPN/100ml)***	***p-value***	***WHO guideline***
Mongo-well	0.0007	Water tanker	0.0125	0.115	0/ml
Bismillahi-well	0.0045	Tricycle	0.0495		
Kapriboa-well	0.0335	Donkey cart	0.135		

Risk of Microbial Infection

Table 3 presents the dose of water ingested (ml), exposed households, pathogen exposure, estimated risk of infection from consumption pathogens in water in the study area. The probability of infection from E. coli diseases was determined for the source water and vended water. The risks of infection from the source water and vended water were high and do not fall within the WHO acceptable limit to human health from pathogenic bacteria of 10^{-5} daily per person per year (World Health Organization, 2014). The health outcomes due to ingestion of pathogen may depend on the exposure route (Howard et al., 2006; Sunger & Haas, 2015). Nonetheless, the effects from exposure to a hazard increases with the pathogen dose ingested (Howard et al., 2006)

Table 3: Quantity consumed, exposed households and the estimated risk of illness from source water and vended water.

Source water	Mean E.coli count (MPN/100ml)	Dose (d)	Exposed Household	Pathogen exposure to drinking water	Exposure to one dose per year	Probability of illness per day $P_{I\ (d)}$	Probability of illness per year $P_{I(A)}(d)$
Mongo -well	0.0007	1.4×10^{-3}	15	5.6×10^{-5}	225	4.3×10^{-1}	2.6×10^{-6}
Bismillahi-well	0.0045	9×10^{-3}	44	3.6×10^{-4}	300	4.3×10^{-1}	2.3×10^{-5}
Kpariboa-well	0.0335	2.7×10^{-2}	112	1×10^{-3}	280	4.3×10^{-1}	6.3×10^{-5}
Water tanker	0.0125	2.5×10^{-2}	15	1×10^{-3}	255	4.3×10^{-1}	4.7×10^{-5}
Tricycle	0.0495	9.9×10^{-2}	44	3.9×10^{-3}	300	4.3×10^{-1}	2.5×10^{-4}
Donkey cart	0.135	6.7×10^{-1}	112	2.6×10^{-3}	280	4.3×10^{-1}	1.6×10^{-6}

Conclusion

The study findings showed some of the physico-chemical parameters analysed (alkalinity, TDS and phosphates) were within the WHO permissible limits for drinking water quality. The detected *E.coli* strains in both vended and water source were high indicating a possible contamination hence not good for consumption. Also, the water sources contained nitrates and was slightly acidity and not safe for public consumption. The importance of regular monitoring, regulation and provision of municipal water supply systems at Kulguduri is therefore emphasized. Human activities such as open defecation, farming, and improper water handling by informal water vendors during transportation and distribution are most likely the reasons for contamination. The findings of the study will provide the East Mamprusi Municipal Assembly and other stakeholders with the necessary information for adequate decision making.

Conflict of Interest

The authors declare that there is no conflict of interest

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