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WATER MANAGEMENT PRACTICES AND QUALITY OF DRINKING WATER FROM SOURCE TO CONSUMPTION POINT IN RURAL COMMUNITIES IN THE DEPARTMENT OF TIASSALÉ, CÔTE D'IVOIRE

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ABSTRACT

This study evaluated the post-supply drinking-water quality in eight rural communities in department of Tiassalé, Côte d'Ivoire, using either a protected hand-dug wells or boreholes supply. Water management practices were documented as a basis for further research to improve household drinking-water quality. The methods used were administration of a questionnaire, observation and by assessing the stored drinking water quality and the water quality of supply point. *Escherichia coli* were used as the indicator of potential health risks. Most of the hand dug wells were *Escherichia coli* positive (100 %), with a more half having (68%) more than 100 colonies in the 100 ml sample (>100 CFU/100ml). 17% of water samples collected at the pump had *Escherichia coli* colonies >100 CFU/100ml compared to 58% at the point of consumption. The bacteriological quality of drinking water significantly declines after collection. Observation of household water management shows that there are multiple points during the collection to use sequence where pollution could occur. The commonality of water management practice would be an asset in introducing appropriate intervention measures.

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INTRODUCTION

The relative importance of water quality versus water quantity, sanitation and hygiene education interventions for protecting the population's health has been the subject of considerable debate (Curtis *et al.,* 2000). Nevertheless, there is broad agreement that good water quality, namely, free of pathogens, is important to human health. Safe water for drinking should be available to every human being, now and in the future (Serageldin, 2000).

Unfortunately water resources are not uniformly distributed and are generally scarce (El-Fadel *et al.,* 2000), so that about 880 million people still lack access to improved drinking water sources (WHO and UNICEF 2008), which affects their social lives and their health (Mansyur *et al.,* 2008). Immediate attention needs to be given to the sustainable supply of water, particularly in rural areas. In many developing countries, community water systems often consist of a well which requires that water be collected, transported, and stored for use in the home.

Although such water systems can supply a water supply, there is considerable potential for deterioration to occur owing to sanitary condition and the amount of handling involved between supply and consumption. Evidence of deterioration of wells water in source, during collection, transportation, storage, or removal for consumption, is abundant within the scientific literature (Wright *et al.,* 2004). Insecure drinking water is the most important cause for the waterborne disease, particularly among young children in developing countries. Causative agents for water borne diseases were virus, bacteria and protozoan. It was estimated that there are 4 billion cases and 2.5 million deaths from endemic diarrheal disease each year (Kosek *et al.,* 2003). The quality of drinking water in developing countries is a prime concern for prevention of water-related diseases (Gundry *et al.,* 2004). However, effective countermeasures to secure the health of people are not well developed without identifying factors of people's daily life in relation to the quality of water for drinking (Jagals *et al.,* 2004). There is a significant need to identify such factors for people living in rural area, who are practicing particular lifestyles, by empirical examination of their daily life and water quality. Studies have been carried out on the deterioration of water quality in supply point by authors such as Ahoussi *et al.* (2012) in department of Tiassalé. However, little is known regarding the water handling practices and impact on water quality to the point of consumption of households in this region. Hence the objectives of this study were to document the normal practice of collection, transport, storage and use, to analyze the bacteriological quality of water at the point of supply and point of consumption and to measure decline in quality, thus providing a conceptual framework for ongoing research aimed at understanding how to prevent water quality deterioration.

MATERIALS AND METHODS

Study area

The study was conducted in eight rural communities, selected in the department of Tiassalé located in South of Côte d'Ivoire. Communities were chosen because of their geographical proximity, their similarity in terms of accessibility, socioeconomic status, employment and education. The main sources of water supply in rural zone are wells which are used for drinking and other domestic purposes. Rural communities are populated and located on sites lacking hygiene, social infrastructure and drinking water supply. These communities did not have flush toilets, many families have to share toilets and therefore, hygiene and sanitation were potential health risks for the people living there. The people had to rely on water that they collect from wells.

Data collection

Administration of a questionnaire

To ensure sufficient data, 400 households were included in the study. Each household was interviewed after the purpose of the study was explained to them and after the interviewees were assured that all data would remain confidential. The questionnaire was in the form of face-to-face interviews. It was developed in line with the objectives of this study and the relevant literature. Modifications were made accordingly based on the feedback received from the conducted pre-test on 15 respondents.

The first section of the final questionnaire focused on background information on respondents (e.g. gender, age, family size, instruction level and occupation), second section focused attitude and practices of household water management, her water sources and hygiene practices.

Observation

Observations were carried out for two consecutive days from 9.00 am to 6.00 pm. Observations were mainly done on housewives and included the recording of all water related activities, such as collecting, transporting, storing, using and the storage conditions of water used for drinking. Any child aged below ten years was also observed if he/she happened to be in the vicinity. Hygiene in domestic environment was verified by observation. Specific details of the household were noted (Ahmed *et al.,* 1998).

Water collection

Sampling was done directly from supply points and after 24 hours at the household storage container. Since it was important to test the same water at levels of storage and supply. Fifty supply points were selected in collaboration with rural authorities and located using a GPS. The choice is mainly justified by their importance for the supply of drinking water of the households. For monitoring the quality of drinking water, sample were taken at random from 100 storage containers. Samples for bacteriological analysis were collected into sterilized 300 mL screw-capped glass bottles. After collection, the bottles were labeled with complete details, including the source of the water, the sample site, the GPS coordinates, the date and time of collection. All samples were stored in an insulated box filled with ice packs and transported immediately to the laboratory.

Microbiological analysis

Microbiological analysis included detection of *Escherichia coli*, which are exclusively faecal in origin, it is bacterial indicator in which used in water quality and health risk assessments and used by the United Nations, the World Health Organization, and a variety of other organizations worldwide. It is normally prevalent in the intestines and feces of warm-blooded mammals including livestock and humans. *E coli* are regarded as the most reliable indicator of faecal contamination and relates to the risk of contracting a water-borne disease (Davraz and Varol, 2011).The membrane filtration method was used and 100 ml of well water was assayed. The bacteria were detected by the conventional culture method (Standard Methods for the Examination of Water and Wastewater, 1995). Results were expressed as Colony Forming Units (CFU) per unit volume. Colonies were counted after inoculation of agar media plates according to the method used. Using the classification system proposed by Lloyd and Helmer (1991), water quality samples have been categorized according to the magnitude of contamination (Table 1), indicating the magnitude of water quality deterioration.

Table 1. Classification of water quality samples according to the magnitude of contamination (adapted from Lloyd and Helmer, 1991)

Grade	CFU/100ml	Risk
A	<1	Safe/No risk
B	1–10	Questionable safety /Low risk
C	11–100	Unsafe/high risk
D	>100	high pollution/ very high risk

Statistical analysis

Statistical analysis was done by using descriptive methods on SPSS 20.0 program. Analysis of variance was then used for probability testing. Student's t test was used to compare the means of microbial parameter for the supply point water and the household water. A probability value of $p<0.05$ was considered statistically significant. EXCEL 2013 was used for the different figures.

RESULTS

Characteristics of the study population

In total 400 households were included in the study. Three hundred thirty three of them used drink water from a hand-dug wells and sixty seven used boreholes. The choice of water source varied according to ease of access. The majority of respondents were woman (99.8%). housewives were invariably the water collectors for their families. Approximately 2.5 % of the respondents had completed superior education, while 8.5% % had not completed high school, 20.7% had some level of primary schooling and some of them were illiterate (68.3%). Agricultural was a principal occupation of woman in rural communities (49.3%) (Table 2).

Table 2. Selected characteristics of the interviewees in study area

Characteristics	Description	n	%
Gender	Male	1	0.2
	Female	399	99.8
Occupation	Trade	90	22.5
	Craft	3	0.7
	Breeding	3	0.7
	Agriculture	197	49.3
	No activity	107	26.8
Instruction Level	Superior	10	2.5
	Secondary	34	8.5
	Primary	83	20.7
	No level	273	68.3

n: Number of positive responses

Water collection and transport

Women (73.8%), man (3.3%) and to some extent girls (23.0%), were mainly responsible for water collection. Several container types were used for water collection including ropes and buckets (83.3%), simple buckets (3%), plastic cans (2%) and bowl (11.7%).The collection containers are cleaned with soap and water in only 28.2% of the cases. The most popular containers for water transport were bowls (69%), cans (12.8%), and buckets (18.2%). Lids were observed only on the can during water transport at the home. Women normally carry the transport container home on their heads and further hand - water contact was often observed as the container was lifted on to the head.

Condition of storage and handling of water

The housewives collected the water from the supply point and transferred it to other containers. Figure 1 shows containers used for storage of water. 20.5 % of the household stored the water in an earthenware, 45.3% used plastic buckets, 15.2 % of household had plastic can, aluminum metal containers were used by 0.8% household, 10 % used plastic cask and 8.2 % of household stored the water in bowl.

While transferring the water, mixing of the collected water with old stored water was observed in most of the households. 74.7% of surveyed households clean the storage container occasionally with soap and 25.3% use only water for cleaning. In many case (84.8%), containers of drinking water storage have a wide opening that allows a cup or similar utensil to be dipped in order to drink water.

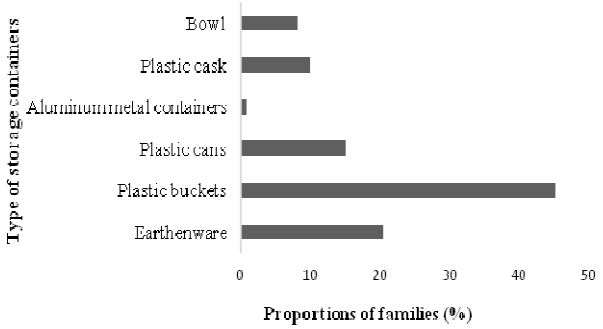

Figure 1. Containers used for storage water at home

Times of water storage at home

Water was stored mainly for drinking and cooking purposes. The results indicated that 77 families had stored during one day, 144 families during two days, 124 families during three days and 36 families during one week and 19 during indefini times (figure 2). In the vast majority of households the drinking-water container was kept covered. Out of a total of 400 household visits 88% of drinking-water containers were covered.

Figure 2. Times of water storage at home

Hands washing

Poor hand hygiene is a major risk factor for transmission of diarrheal disease by féco-oral. We asked women before/after which activities they used soap to wash their hands in our research. Around 20 % stated they washed their hands with soap before food preparation, 27 % before eating and 13.6 % after defecation.

Water treatment at home

In the majority of families, 78.2% of women felt that the water was of good quality and could be consumed directly, without treatment. 21.8% think that water cannot be drunk without treatment. Out of 21.8%, 2.3% do not perform any treatment, 4.3% filters water using white tissue, 5.4% decantation practice, 8.8% use chlorine and 1% naphthalene (Figure 3).

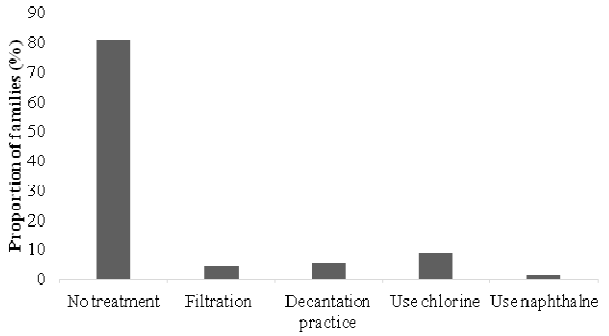

Figure 3. Proportion of method of water drinking treatment

Water quality

Table 3 shows the mean bacteriological water quality measured at source and in the household storage container. It can be seen that substantial post-supply deterioration occurs. The calculated probability values demonstrate that water quality becomes significantly worse following collection and storage. Deterioration is particularly noticeable in the case of the borehole water supply. It is also evident that household stored water originating from the borehole is of significantly better quality than that drawn from hand-dug wells.

Table 3. Values mean CFU/100ml in water samples measured at source and in household storage containers with calculated probability values

Water supply point	Water quality at source (sample size)	Water quality in household storage container (sample size)	P-value
Hand-dug well	18 (6)	119 (12)	<0.0001
Borehole	117 (44)	200 (88)	<0.0001

Table 4. Classification of water quality samples according to the magnitude of contamination (adapted from Lloyd and Helmer, 1991)

Classification of microbial water contamination		Borehole		Hand-dug well	
		Proportion (%) of samples according to risk category		Proportion (%) of samples according to risk category	
Escherichia coli CFU/100ml	risk	Supply point	Consumption point	Supply point	Consumption point
<1	Safe/No risk	83	0	0	0
1–10	Questionable safety /Low risk	0	0	0	0
11–100	Unsafe/High risk	0	42	32	0
>100	high pollution/ Very high risk	17	58	68	100
		100%	100%	100%	100%

Using the classification system proposed by Lloyd and Helmer (1991), water quality samples have been categorized according to the magnitude of contamination (Table 4).It provides a clear illustration of the proportion of samples that moved from one grade of water quality to another, indicating the magnitude of water quality deterioration. For example, 17% of water samples collected at the pump had E. coli colonies >100 CFU/100 ml compared to 58% at the point of consumption.

DISCUSSION

This study has provided further evidence that water quality deterioration can and does occur between the points of supply and consumption. It has been shown that it can deteriorate to the extent that it is considered grossly polluted according to the classification system proposed by Lloyd and Helmer (1991). Results of microbiological analyses of water at supply point and point-of-use demonstrated the variation of bacterial contamination of water stored in containers for drinking in household. The bacterial loads of *Escherichia Coli* increased gradually from source to point of use. Practices between water collection and use could be originally of the re-contamination in study area. In 71.8% of the cases, the collection containers are cleaned only with water without the use of soap or other detergents. There were buckets attached to ropes on the ground before and after the water was collected. Women normally carry the transport container home on their heads and further hand-water contact was often observed as the container was lifted on to the head and transported at home.

Transport containers were without lid during the transport of water at home. In many case (84%), containers of drinking water storage have a wide opening that allows a cup or similar utensil to be dipped in order to drink water. These results corroborate those found by Trevett (2004) in rural Honduras, they examined water quality in 43 households and observations during collection, storage and usage practice and their results indicated a substantial water quality deterioration between the points of supply and consumption. Deterioration occurred regularly and frequently, and was experienced by the majority of study households, over a 2-year period. Several other handling factors are potentially implicated in post-supply water quality deterioration. These include the use of separate containers for collection and storage, inadequate washing of the container, hand contact and according to (Ahmed *et al.,* 1998) the material from which the storage container is made. In our research, hand contact with drinking water was regularly observed at all stages of the collection to consumption process.

We asked women before/after which activities they used soap to wash their hands in our research. No mention was made of washing hands with soap before carrying out any drinking water practice. It is arguable that hand-water contact is unavoidable in situations where water must be collected, transported and stored. Consequently, if hands are unclean there is a high risk that drinking water will become contaminated as a result of contact made during normal household water management. Current household water handling and hygiene practices leave drinking water vulnerable to contamination and may be associated in pollution of drinking water at home.

According to Trevett (2003) hand-water contact is a principal cause of the re-contamination of drinking water. Wright *et al*. (2004) in their study, showed that the majority of contamination of drinking water occurs during collection, storage, and use. The level of instruction, especially of women in rural areas, is typically very low in developing countries. In the villages included in our research, nearly half of households surveyed had not received any formal schooling, and only a quarter had completed primary education. In these conditions, knowledge of good hygiene practice will be limited. A

significant deterioration of the bacteriological quality of water during collection and handling, contributing to the persistence of water-borne illness. In a study carried out in a peri-urban community in Peru, Yeager *et al.* (1991) concluded that children were twice as likely to suffer a high incidence of diarrhoea in households where water was stored in containers without a tap. Singh *et al.* (1995) report that storing water in wide-mouthed containers and using a glass or mug to draw water were important risk factors for cholera cases. Water quality deterioration can be significantly reduced using specially designed storage containers (Empereur-Bissonnet *et al.,* 1992; Roberts *et al.,* 2001), chlorination at the point of use and good hygiene practices. Roberts *et al.* (2001) carried out an intervention study in a Malawi refugee camp using an improved container. A 31% decrease in diarrhoeal disease was observed in children under 5 years of age where households used the special container.

A meta-analysis of interventions such as chlorination at the point of use and hand washing initiatives showed an improvement in the quality of the stored drinking water and a reduction of diarrheal episodes by 39% and 45% respectively (Fewtrell *et al.,* 2005). An appropriate intervention programs necessary to provide safe drinking water, any intervention must consider the local practice and socio-cultural factors, the knowledge and attitude of the people to understand the water usage, water handling and personal hygiene impact on health (Banda *et al.,* 2007).

Conclusion

The results of this study indicated that the microbial quality of drinking water stored in containers showed a significant recontamination and was associated with water source, practices hygiene and water management. It is clear that there are a great number of points in the sequence of collection, transport, storage and use during which contamination could be introduced. Hands, containers, dippers, dust, insects and animals, are all potential sources of contamination. Lack of protected water supply and microbial water treatment in the rural area creates a situation ideal for the spread of diarrheal disease. Interventions in water supply and sanitation infrastructure, the hygiene committees imparting hygiene messages through health centers, radio and local theater need to be implemented within an integrated multidisciplinary framework. Education dealing with water management and technology should be an integral component of water supply programs in developing countries. Practices may be improved by improving supply point maintenance, covering containers, avoiding careless or sudden changes in use of water storage containers, in addition to other local water handling practices. Further research on water contamination and hygiene during supply, transportation, and household management is recommended.

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