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Point of Collection to Point of Use Drinking Water Changes and Cognizance, Attitudes and Practices in Segou Region, Center of Mali

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ABSTRACT

This paper presents the results of a study to evaluate water quality related legislation and policies, institutional arrangements and ability for water quality monitoring by means of a desktop review of pertinent documents and Main Informer Interviews (MII) to determine the institutional ability exigencies for expanding the surveillance system of water quality; to determine the sureness and likely drinking water deterioration furnished to communities from point of collection to point-of-use, and evaluate the potential role of consumers' Cognizance, Attitudes, and Practices. This part was carried out through focus group discussion, MII, questionnaires, laboratory analysis, and systems of geographic information, which were achieved in 1098 households of 29 villages in four rural communes of Segou region of Mali; to produce a documentary to raise conscientiousness among decision-makers of links between managing drinking water from point of collection to point of use, treatment, and consumers water quality. The outcomes reveal that apart from the pH, EC, TH, and Mn, the protected water sources were good quality at source. Yet, there was a degradation in water quality between point of collection and point of consumption in 66.67%, 30.23%, 31.03%, 10%, 35%, of surface water, shallow wells, dug wells, boreholes, and hand pumps, respectively.

INTRODUCTION

Water destined for human consumption, and domestic uses are essential to maintaining a public health and it contributes to the quality of life of households through the provision of basic needs of water and sanitation. However, in low-income nations, particularly in rural areas, water distribution is consistently low, since high water quality is necessary and considerable investments generally required for equipment. Some noteworthy statistics from the WHO/UNICEF Joint Monitoring Program 2017 (JMP) for Water and Sanitation reveal that in such areas, roughly 748 million people do not have access to sufficient safe drinking water. Additionally, 2.4 billion human beings lack access to improve sanitation conditions (WHO & UNICEF 2017). Governments, the World Health Organization (WHO) and several other development partners have tried to extend water distribution systems in order to ensure potable water supply in low-income countries. Thanks to their attempts, more than 2.6 billion human beings were able to access safe drinking water between 1995 and 2015. Even nowadays, Sub-Saharan Africa faces the tremendous challenge in increasing the use of improved drinking-water facilities, and more than 37% of the population in this area still use unimproved sources (WHO & UNICEF 2017). In Mali, hundreds million dollars has been invested in water distribution systems from 2005 to 2013, and roughly 1,700 modern water points have been built for 62% of the overall rural inhabitants by the end of 2013 (UN-WATER/WWAP 2016). Despite all these efforts, roughly more than half of the population does not have access to improved drinking water sources.

As noted by Coulibaly. (2009), water intended for human consumption, and domestic use increased in households that have recently accessed improved water supplies. The consumption then goes from 4 liters per day and per capita to 10 liters in the rural areas of Mali (WHO/UNICEF Joint Monitoring Program. 2015). In rural Cameroon, inhabitants used 5 liters per day and per capita prior and 15 liters per day and per capita after the installation of community taps (Tyler et al. 2017). Designed water supply capacity frequently does not respond the growing request for water. This is an obstacle to the supply of drinking water in rural zones even after receiving improved water supply (Jessica et al. 2014). As a result, restrictive policies such as irregular water supply are extensively performed at the rural levels. However, several studies have criticized these approaches for their non-equitable effects, health risks, and capacity to bring about water panic (Kumpel & Nelson 2013). Where improved drinking water has been provided to such communities, contamination of water during storage, collection and transportation is of concern since contamination would result in water that is unsafe for human consumption (Jagals et al. 2004).

The most common adverse health effects associated with bad water quality is diarrhea. Approximately 1.5 million deaths annually are due to diarrheal disease (WHO & UNICEF 2017). In addition, it is calculated roughly that 58% of the latter figure (842,000 deaths annually), is attributable to unreliable drinking water supply and sanitation, and includes 361,000 deaths of children younger than five years, notably, in low income countries (WHO 2014;

Amadou Toure et al. 2018). In Mali, diarrhoeal diseases are responsible for about 27,720 or 22 per cent of the annual deaths of children under five years (Halvorson et al. 2011). To meet the challenges of child survival, the government of Mali launched in 2004 a Water Supply and Sanitation Program aimed at improving access to Safe Drinking Water and improving environmental health.

For about the rearmost 30 years, drinking water supplies and sanitation have received a great deal of internationally attention and were presented as a main step in decreasing this preventable burden of disease through decentralized water supply interventions as a key strategy to address disparities in access. In spite of trillions of dollars spent on rural water and sanitation, mortality rates by water-borne pathogens have indeed increased (Iyer et al. 2006).

Fewtrell et al. (2005), in the meta-analysis found that many health research indicated that a combination of interventions such as safe affordable drinking water supplies, sanitation, hygiene, household water treatment, and education account for a significant role in the decreasing of diarrheal diseases. One of unexpected results have been that improved hygiene decreased diarrheal disease-related mortality by 45 percent in certain cases, while improved drinking water sources only reduced the incidence of disease by 25 percent. Other studies declare that the simple availability of safe drinking water and sanitation facilities is not sufficient to guarantee a statistical decreasing in morbidity due to diarrheal disease, indicating that hygiene conduct has a significant effect on disease decreasing (Gundry et al. 2006; Pande et al. 2008). Indeed, behaviors in water handling post-pumping may also result to changes in quality, such changes can take place within minutes of water withdrawal and negate the original quality (Gundry et al. 2009). In addition, the conditions for collecting, transporting and storing drinking water may contribute to pollution (Trevett et al. 2005). However, it is necessary to develop access to household water treatment systems, water storage and water quality monitoring at the point of use. Although there is global evidence that simple, low-cost interventions at the household and community level can reduce the risk of diarrhoeal diseases and death (Onabolu et al. 2011), there is no contextual information to clarify the effectiveness of home-based water treatment in the Segou region of Mali. The study have been conducted as a first step towards promoting a global community based drinking water quality system in the Ségou region of Mali.

The aims of our study are as follows: (1) to evaluate institutional ability for household level drinking water quality surveillance in Segou region; (2) to determine the sureness and likely drinking water deterioration furnished to communities from point of collection to point-of-use, and (3) to determine the contributing role of the study area households' water and sanitation related Cognizance, Attitudes and Practices (CAP) to the noticed degradation in quality.

MATERIALS AND METHODS

Description of the study area

Segou region is located in the center of Mali between 12°30'and 15°30' N latitude and 4° and 7° W longitude, with a total area of 62 504 km² and a population of 2 338 349 based on the 2009 census (RGPH 2009). The region of Segou is composed by 118 Communes including 3 urban communes (Segou, San and Niono) and 115 rural communes (PROMISAM 2011). It is bounded to the North by the Islamic Republic of Mauritania, to the South East by Burkina Faso, to the East by the Mopti region, to the North East by the Tombouctou region, to the South by the Sikasso region and to the West by the Koulikoro region. The sudano-sahelian-type climate is marked by the alternation of 2 periods (i.e., 2 seasons): a rainy period from June to September and a longer dry season from October to May. Precipitation is quite low, with an annual mean of up to 625 mm/year; the highest precipitation recorded in August. The average annual temperature is around 28°C with a significant duration of sunstroke which varies from 2500 to 3000 hours. Residents of the different villages of the area practice agro-pastoralism, relying mainly upon agriculture, including millet, groundnut, cotton, and vegetables.

Data collection

Data collection methods of the three different parts of our study are described as follow:

(1) A specialist have been hired by the regional hygiene office of Segou region with the support of the Ministry of Health of Mali. This person has the task of obtaining and documenting information from the pertinent stakeholders in Segou region through Main Informer Interviews (MII) on water quality related legislation and policies. Also on institutional arrangements and ability for water quality monitoring, funding mechanisms, accessibility of water quality monitoring gear, and defiance in monitoring/tracking water quality. The techniques of data collecting comprised desktop review of pertinent documents, MII with concerned actors, and laboratories inspection. The concerned actors comprised the Ministry of Environment, Sanitation and Sustainable Development, Ministry of Health and Public Hygiene, Ministry of Energy and Water, National Health Directorate, Regional Hydraulics Office of Segou, SOMAGEP (Malian Society for Drinking Water Management), the Rural Water, and Sanitation Agency and the Primary Health Care Centers. The results found has then been presented at a communal seminar of the board regional in Segou.

(2) The study has been carried out in 29 villages in four rural communes (Pelengana, Sebougou, Sakoïba, Togou) of Segou region. These four communes possess similar climate and socio-economic characteristics including low income, and poor infrastructure. The cross-sectional descriptive study used a three-step sampling approach. First, forty percent of the rural communes of Segou region (RCSR) were randomly selected based on the 2009 general population census. Second, forty percent of the villages were randomly selected in each of the selected rural communes and proportionally allocated sample size to the selected villages based on the proportion of the population of each commune to the total population of the region. Finally, households were randomly selected for the questionnaire survey.

Questionnaires have been fastidiously completed from 1098 respondents, and also 105 water sources from 29 villages were selected. Also, 226 water samples were collected from households for physical, chemical and bacteriological analyzes. These include 105, 105, 12, and 4 samples taken before, after storage, sediments in the storage container, and water packaged in bags, respectively (Table 1).

A team was trained in order to collect qualitative and quantitative information. The survey was carried out through focus group discussion, Main Informer Interviews (MII), a semi-structured questionnaire, a checklist of observations, analysis of laboratory, and systems of geographic information. The oldest individual in the household have been interviewed. The information collected included information regarding type and functionality of water sources, likely sources of contaminations through environmental factors (households' latrine status, garbage pile near households, and open drains), as well as household level (conditions of water and sanitation facilities, water handling, treatment, storage, sanitation, and hygiene practices). It is worth noting that the information found through observation has been used to discuss the truthfulness of the survey results.

The physical, chemical, heavy metals, and microbiological characteristics of the 105 water sources from villages selected have been also investigated. These water sources include 20 hand pumps, 10 boreholes, 29 dug wells, 43 shallow wells, two streams, and one pond. The water of the sources selected has been tracked down in 105 of the 1098 households selected in order to connect water taken from a household to its source. Water samples have thereby been taken from the sources, the households prior storage, and at least 24 hours after storage into the household container. Samples were collected between 08 00hrs and 10 00hrs into a 1L sterilized polyethylene flacon and, at each sampling point, two samples were collected in separate polyethylene flacons. All collection flacons were firstly washed with detergent, secondly rinsed with tap water and distilled water, and then rinsed three times with the sampled water from the respective source stated above. Different sampling methods were used for various categories of water sources. Samples from the dug wells, and shallow wells were collected with weighted buckets (50cm below the water table). Boreholes and hand pump samples were taken after pumping for 5min. Surface water samples were taken at a depth of 30 cm below the surface. Regarding collecting household water samples, it was used the same techniques as the inhabitants, ie, used a cup or a small calabash to serve water. Noted that for chemical and bacteriological analyses, separate samples have been carefully collected and at each point a vial was filled with the site water sample while adding HNO_3 to 5% in order to prevent bacterial survival. The water samples were fastidiously tagged and keep in a cooler at temperatures ranging from 0°C to 4°C. Finally, they have been delivered to the microbiology laboratory within six hours of their collection for further processing. In the laboratory, acidified water samples have been used for heavy metal analysis, whereas water samples that did not contain acid have been used for the remainder of the analysis.

Samples of water from sources, prior storage, and 24 hours after storage have been analyzed for physical, chemical, heavy metals and bacteriological parameters, in accordance with the American Public Health Association (APHA) Standard Techniques (APHA 2012). The hydrogen potential (pH), electrical conductivity (EC), colour, and turbidity have been measured in place employing a multimeter (Model HQ 40d, HACH, USA). Total dissolved solids (TDS), and total suspended solids (TSS) have been measured employing a multimeter (Sension-156, Hach, USA). Chloride (Cl^-), Total hardness (TH), and alkalinity/acidity were ascertained in the laboratory using the standard titrimetric technique. The nitrate (NO_3^-) and ammonium (NH_4^+) concentrations were ascertained using an ultraviolet spectrophotometer, HACH 2800, employing standard ethylene diamine tetra-acetic acid (EDTA) as given American Public Health Association (APHA 2012). The concentrations of lead (Pb), fluoride (F), arsenic (As), iron (Fe), zinc (Zn), copper (Cu), chromium (Cr), cadmium (Cd), and manganese (Mn) were determined using flame Atomic Absorption Spectrophotometer (AAS) Shimadzu model AA 6300. With regard to bacteriological analyzes, specific indicators of environmental and faecal contamination (Total coliforms and Escherichia coli) were ascertained using Most Probable Number (MPN); while faecal coliform has been ascertained using Plate Count using EMB Agar as given American Public Health Association (APHA 2012).

(3) A theatrical troupe and a TV host were hired to produce a scenario. Pamphlets were distributed to support and better understand the scenario. The scenario included areas such as the significance of water to all forms of life, the possibility for water to become a vector for water-borne diseases, drinking water quality issues in urban and rural areas, the drinking water management method, drinking water issues faced by technocrats, and the roles of communities and authorities in managing drinking water from point of collection to point of use. Representatives of the authority, as well as urban and rural consumers were interviewed about the real situations related to the scenario.

Table 1. The size of the population sample and size of water sample in the rural communes of the Segou region.

RCSR	Target villages	Number of selected respondents	Sample of source water	Households water samples before storage	Households water samples after storage	Water packaged in bags	Storage vessel sediment heavy metal sampling
Sakoïba	Benni	39	4	4	4	1	
	Chola	39	4	4	4	0	1
	Dagala	39	4	4	4	0	
	Diakobougou	39	4	4	4	0	1
	Diassebougou	39	4	4	4	0	
	Djenina	39	4	4	4	0	

RCSR	Target villages	Number of selected respondents	Sample of source water	Households water samples before storage	Households water samples after storage	Water packaged in bags	Storage vessel sediment heavy metal sampling
	Koune	39	4	4	4	0	
	Siguila	36	3	3	3	0	1
	Sirakoro	37	3	3	3	1	
	Douga	39	4	4	4	0	
	Total	**385**	**38**	**38**	**38**	**2**	**3**
Pelengana	Banankoro	33	3	3	3	0	1
	Bapho	28	2	2	2	1	
	Benzana	33	3	3	3	0	
	Diakoro	33	3	3	3	0	
	Djigo	33	3	3	3	0	1
	Donzana	32	3	3	3	0	
	Kolotomo	33	3	3	3	0	
	Koukoun	32	2	2	2	0	
	Fahira	29	2	2	2	0	1
	Fanzana	33	3	3	3	0	
	Total	**319**	**27**	**27**	**27**	**1**	**3**
Sebougou	Sando-Sido	46	5	5	5	0	
	Sekoro	46	5	5	5	0	1
	Banakoroni	46	5	5	5	1	1
	Dougoukouna	46	5	5	5	0	1
	Total	**184**	**20**	**20**	**20**	**1**	**3**
Togou	Kani	42	4	4	4	0	1
	Pogo	42	4	4	4	0	
	Tesserebougou	42	4	4	4	0	1
	Zanabougou	42	4	4	4	0	
	Nablabougou	42	4	4	4	0	1
	Total	**210**	**20**	**20**	**20**	**0**	**3**

RESULTS

Part 1

The 2007 National Integrated Water Resources Management Policy Bill view to sustain initiatives aimed at reducing and preventing the pollution of water resources. Stakeholders surveyed had more information on WHO's drinking water guidelines than on Malian drinking water quality standards. The Ministries of Energy and Water, Health and Public Hygiene, the National Directorate of hydraulics, and Malian Society for Drinking Water Management are the main structures legally in charge of different aspects of drinking water quality management. The actual structures and the National Drinking Water Quality monitoring structures are legally in charge of the state level. The municipal authorities, communities, as well as consumers as well have their part of responsibilities. According to the interviews, stakeholders had poor knowledge about their roles. It is important to note that at the moment of the interview, although the monitoring of water quality was performed by municipal authorities, and Malian Society for Drinking Water Management (SOMAGEP), deficiencies have been signalized from the point of view of personnel qualification, retraining, field site transportation, control of quality, record keeping, and equipment standardization and reactants and infrastructure of laboratory.

Part 2

Description of Socio-Demographic and Economic Characteristics of the respondents

Investigations were carried out among 1098 persons. Overall, 79.33% (871/1098) of the respondents were represented by males, and 81.15% (891/1098) were married. It is worth noting that 69.76% (766/1098) of the respondents have illiterate, and 72.4% (795/1098) have a daily income of fewer than 500 FCFA i.e., less 1USD. The majority (89.62%) of respondents are farmers/fishermen, 89.98% (988/1098) of which are of Bambara ethnic group, and the most part (90.8%) are Muslim.

Protection of drinking water provided to the villagers

Physicochemical parameters have been tested at the source (i.e., point of collection) to point of use (i.e., household level). However, parameters examined have been compared with World Health Organization Guideline for Drinking Water Quality (WHO & UNICEF 2017). The outcomes have been regrouped for 29 villages in four rural communes of Segou region, a sub analysis has likewise been performed within the communes.

Physicochemical and microbial quality of drinking water

The average pH values for shallow wells (SW) (8.7) and hand pumps (HP) (8.6) from 29 villages sampled in the four communes exceeded the allowable limit (6.5–8.5). Once disaggregate to the communes level all SW except Togou commune had allowable levels, all HP kept outside permissible limits except in Pelengana commune and the pH of dug wells (DW) in all communes except Pelengana and Togou fell outside the permissible limits. The average samples color from point of collection and households storage were below the WHO (15HU) guidelines for drinking water, apart from the point of collection and storage samples from stream and pond, which have 187.35 and 54.47 Hazen Units (HU), respectively. The Average values for electrical conductivity (EC) of the water samples from source for SW, HP, BH, DW, surface (stream and pond) were 3002.21, 2352.40, 1974.56, 2387.36, 1075.80 µs/cm, respectively, and were all above the permissible limits of 1000 µs/cm. The same applies to households storage for SW, HP, BH, DW, surface whose average values were 2871.5, 2236.32, 1576.3, 2169.25, 1215.42 µs/cm, respectively. The average samples turbidity from source and households storage falls within the recommended limits of 4 NTU, apart from the source and storage samples from surface whose values were 6.45 and 7.19 NTU, respectively. Similarly, except the average values for TDS from the surface and storage samples from surface whose values (612.52, and 609.30 mg/L, respectively) excess the recommended 600 mg/L, the TDS of SW, HP, BH, DW water samples in all the communes falls within the WHO guideline value. The Cl^-, NO_3^-, and TH concentrations were within the permissible limits set by the WHO guideline for drinking water quality. However, there have been some variations within the communes, namely in the Togou commune, where the average TH concentrations of stored household waters from HP, and BH and the average NO_3^- contents of SW, and DW sources in Sakoïba commune are outside the permissible limits (Table 2).

The outcomes of the analysis of the heavy metals of source waters and sediments from stored household waters showed that among the samples analyzed among other things lead, fluoride, arsenic, iron, zinc, copper, chromium, cadmium, and manganese, the concentrations of Mn of most samples were outside the permissible limits in the four communes, whose 100% in Sebougou commune excess the recommended 0.4 mg/L, and varied between 0.442 and 0.692 mg/L. The results presented in Table 3 gives an indication of households storage sediment samples from Sebougou commune.

The values of bacteriological parameters obtained for sources, and stored household waters samples, apart from of boreholes (BH) as noticed by TC maximum values, were all beyond the permissible limit of 0 per 100 mL set by WHO guideline for drinking water quality, with the shallow wells, surface being highest at source (81MPN/100mL and 523 MPN/100mL respectively), and likewise at household storage (318 MPN/100mL and 412MPN/100mL respectively).

Table 2. Certain chemical parameters of water samples from sources and stored household waters in the 4 communes

Provision	Parameter	WHO limits	Sakoïba			Pelengana			Sebougou			Togou		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Source	**Cl^- (mg/L)**	250												
HP			9.6	22.5	13.2	8.2	11.6	9.1	5.5	7.9	6.3	9.8	147.5	69.4
BH			5.1	9.2	6.8	6.7	8.1	6.9	5.1	5.7	5.3	6.6	87.2	41.7
DW			3.5	21.5	11.2	2.7	18.7	9.1	3.4	9.2	5.3	5.4	75.1	36.2
SW			8.2	14.5	11.2	3.4	9.5	5.3	5.3	8.7	5.9	14.2	58.6	22.5
Surface			3.1	3.1	3.1	4.6	4.8	4.7	5.9	7.1	6.3	3.2	8.7	5.6

Provision	**Parameter**	**WHO limits**	**Sakoïba**			**Pelengana**			**Sebougou**			**Togou**		
			Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Households storage														
HP			9.7	22.8	14.5	8.0	12.1	9.3	5.2	7.5	5.3	9.8	153.6	71.2
BH			3.8	18.5	10.7	6.9	9.1	7.2	5.3	6.4	5.6	6.2	79.7	39.5
DW			3.2	20.3	10.9	2.9	20.4	10.1	3.5	9.3	5.6	5.2	70.5	32.5
SW			7.4	12.2	8.5	3.5	10.2	6.3	5.1	7.3	5.6	14.0	58.5	22.1
Surface			2.6	3.2	2.8	3.4	3.4	3.4	6.2	6.2	6.2	3.5	8.9	5.7
WP			3.1	3.1	3.1	1.5	1.5	1.5	3.6	3.6	3.6	-	-	-
Source	**TH (mg/L $CaCO_3$)**	500												
HP			206.5	387.3	248.6	130.8	194.3	143.5	77.2	147.5	112.4	366.5	601.6	487.3
BH			55.5	97.2	63.8	36.0	46.1	39.3	26.8	95.6	47.5	353.4	574.2	423.5
DW			22.1	22.1	22.1	87.3	94.2	91.3	36.3	89.2	56.7	121	183.4	146.8
SW			152.3	250.1	175.4	102.4	105.2	103.1	52.8	74.9	63.5	124.2	201.4	147.6
Surface			45.3	48.9	45.9	100.5	107.6	102.1	100.7	100.7	100.7	100.9	121.0	107.3
Households storage														
HP			212.2	416.3	341.5	136.5	201.6	159.5	78.3	145.7	113.4	378.8	749.5	576.4
BH			58.5	98.4	69.7	36.2	45.7	38.3	28.6	97.5	56.3	392.3	710.7	512.8
DW			24.3	25.1	24.4	88.4	91.6	89.6	39.3	89.0	47.3	126.8	191.4	139.5
SW			154.2	201.4	166.5	102.4	103.7	102.6	56.6	56.6	56.6	126.3	147.5	131.3
Surface			47.7	49.3	48.2	101.5	105.2	102.8	100.5	100.5	100.5	108.7	112.3	109.7
WP			21.5	21.5	21.5	12.8	12.8	12.8	12.3	12.3	12.3	-	-	-
Source	**NO_3^- (mg/L)**	50												
HP			12.5	23.8	17.4	10.8	19.6	14.1	10.0	17.8	13.6	19.3	31.2	24.2
BH			28.5	34.4	31.5	18.2	23.5	21.4	18.7	31.7	23.9	22.4	34.2	28.7
DW			35.6	74.5	61.3	10.2	32.8	19.3	9.9	23.4	13.7	21.3	37.5	29.7
SW			41.8	79.6	67.7	16.5	41.0	26.8	15.2	37.4	21.6	32.5	48.2	39.3
Surface			22.3	26.4	23.3	25.9	31.1	27.5	26.4	29.5	27.4	24.7	27.5	25.8
Households storage														
HP			10.5	17.7	13.2	10.0	14.5	12.3	8.5	12.5	10.1	14.5	24.3	16.6
BH			21.4	24.8	22.6	17.0	19.4	18.3	15.4	24.5	21.2	20.2	30.1	24.8
DW			30.2	41.8	35.4	10.0	28.7	19.3	9.2	19.6	13.7	18.8	26.3	23.4
SW			32.6	46.8	40.1	14.3	31.5	24.2	12.6	24.5	19.7	26.4	31.3	28.7
Surface			39.3	41.5	39.8	22.5	28.7	24.8	23.5	26.7	24.5	21.5	23.6	22.4

Provision	Parameter	WHO limits	Sakoïba			Pelengana			Sebougou			Togou		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
WP			1.4	1.4	1.4	2.1	2.3	2.2	1.7	1.7	1.7	-	-	-

Table 3. Some Heavy metal parameters of household container sediments in Sebougou commune

Sample identification code	Mn (mg/L)	Pb (mg/L)	F (mg/L)	As (mg/L)	Fe (mg/L)	Zn (mg/L)	Cu (mg/L)	Cd (mg/L)	Cr (mg/L)
WHO limits (mg/L)	0.40	0.01	1.5	0.01	-	3	2	0.003	0.05
1S3SAN01	0.451	0.006	0.871	0.003	0.105	0.910	0.777	0.0007	0.007
1S3SAN01	0.442	0.004	0.852	0.001	0.101	1.024	0.721	0.002	0.005
1S3SAN02	0.506	0.004	1.004	0.0008	0.115	1.037	0.793	0.0005	0.005
1S3SAN02	0.522	0.003	0.784	0.001	0.201	0.821	0.612	0.001	0.004
1S3SAN03	0.478	0.001	1.009	0.0006	0.102	1.102	0.741	0.001	0.005
1S3SAN03	0.507	0.001	0.876	0.001	0.074	1.074	0.635	0.0008	0.008
1S3SEK01	0.551	0.007	1.201	0.002	0.057	0.873	0.901	0.002	0.007
1S3SEK01	0.527	0.005	1.013	0.001	0.102	0.442	0.982	0.001	0.007
1S3SEK02	0.499	0.002	0.912	0.0004	0.083	1.102	0.893	0.002	0.005
1S3SEK02	0.507	0.003	1.047	0.001	0.085	1.053	0.915	0.0005	0.002
1S3SEK03	0.489	0.002	0.684	0.001	0.108	1.010	0.891	0.001	0.005
1S3SEK03	0.530	0.001	1.005	0.002	0.074	1.000	0.870	0.002	0.006
1S3BAN01	0.456	0.003	0.910	0.004	0.081	1.082	0.700	0.0006	0.004
1S3BAN01	0.464	0.001	0.865	0.002	0.074	0.857	0.887	0.001	0.002
1S3BAN02	0.471	0.005	0.793	0.001	0.105	0.745	0.569	0.001	0.009
1S3BAN02	0.445	0.003	0.767	0.003	0.099	0.761	0.691	0.002	0.009
1S3BAN03	0.692	0.001	1.001	0.0005	0.108	1.041	0.830	0.0004	0.006
1S3BAN03	0.583	0.002	1.021	0.001	0.083	0.881	0.900	0.001	0.004
1S3DOU01	0.604	0.004	0.668	0.003	0.753	0.854	0.722	0.002	0.008
1S3DOU01	0.623	0.004	0.691	0.002	0.103	1.001	0.699	0.001	0.004
1S3DOU02	0.597	0.001	0.827	0.003	0.098	1.022	0.898	0.0008	0.004
1S3DOU02	0.609	0.002	0.861	0.002	0.086	1.002	0.558	0.003	0.004
1S3DOU03	0.598	0.001	1.003	0.0009	0.063	0.899	0.881	0.001	0.002
1S3DOU03	0.567	0.003	1.071	0.001	0.069	0.741	0.858	0.002	0.005

Sample identification code (1S3SAN01, 1S3SEK02, 1S3BAN03, 1S3DOU01): 1S3 indicates the Sebougou commune, the following 3 characters indicate target villages as follows: SAN= Sando-Sido, SEK= Sekoro, BAN= Banakoroni, DOU= Dougoukouna. The last 2 characters indicate the number of sample in the respective villages.

Tracking of water quality changes from point of the collection (source) to point of use (household)

The microbiological quality of drinking water has been monitored from point of collection to point of use. This has been accomplished by taking water samples in triplicate from 105 menages (i.e., households) from point of collection to recovery vessel (prior it was shed into the storage vessel and after to storage). However, although there was no great change in Cl^-, and NO_3^- values from point of collection to recovery vessel, there were significant variations in the E. coli, TC, and FC counts from point of collection to recovery vessel.

Amongst the households (3) that drew water from the surface water, 1 indicated a decrease in the number of total coliforms from the collection point to households storage of 120 MPN/100 mL at 52 MPN/100 mL. It is was mentioned that this household practices at least two home water treatment method notably sedimentation and tissue filtration, washes hands with soap and cleans the transport container prior to taking water. As for the coverage of the drinking water storage containers, the household does so. They have a toilet facility and mentioned that they clean it once a day. The other two households experienced an augmentation in TC counts from point of collection to household storage. It is worth noting that the water handling practices of the three households were alike, apart from the household with the greatest augmentation, reportedly cleaned their toilet every three days compared to the remaining two households that would have cleaned once a day.

Thirty percent (13) of the samples collected from 43 shallow wells and tracked to point of use (i.e., household storage) in the four communes, increased the number of TC from point of collection to point of use, with the percentage augmentation ranging from 17.48% to 19 000%. This worsening has been seen yet although all except four households reportedly used tissue filtration method to treat their drinking water. All but two households, whose TC count had increased by 900%, had toilets, covered storage vessels, and allegedly washed their hands with detergent. 35% (15) presented a reduction in the number of TC ranging from 91.5% to 96.9%. It is important to note that there was no distinct relationship with water management practices. The household with the highest diminution indicated that it did not use a home water treatment method to treat their drinking water. The bacteriological quality of the others 35% (15) households have been kept from point of collection to households storage. Each household had a toilet but only three households would have used aquatabs to treat their water.

Thirty-one percent (9) of the samples collected from 29 dug wells and tracked to point of use in the four communes increase of 180% in the number of TC from point of collection to household storage, in spite of the presumed treatment of its water. Three households experienced a 90% reduction, the common practice among them being the presence of toilets and covers. The remaining 59% (17) households kept TC levels from point of collection to households storage. The only common water management practice between them was toilet facilities presence which they affirm cleaned once a day.

Of the ten boreholes tracked to ten households in the four commune of Segou region, one denoted a percentage augmentation of 400% in TC count from point of collection to household prior to shedding into the storage vessel (HPSV), despite the treatment of this waters is carried out. In addition, three households presented a percentage diminution of 100%. However, they had toilets, covers as common practices. The other six households presented unchanged TC count from point of collection to households storage. The common practice among them being the presence of covers and toilets which they affirm cleaned every day (Table 4).

Amongst the 20 hand pumps tracked, 35% (7) presented a percentage augmentation in TC count of 870% and 1500%. The most common practices were that they covered their water and had toilets that they cleaned three times a week. 20% (4) households presented a percentage diminution in the number of TC ranging from 55.5% to 99.5%. It is was noted that those households practices tissue filtration treatment method to treat their water, covered storage vessels, and allegedly washed their hands with soap. They have a toilet facility and mentioned that they clean it once a day. The others 45% (9) households did not change in TC levels from point of collection to household's storage, covered and treated their water, and all had toilets that they felt were cleaned at least once a day.

Table 4 Water quality of samples tracked from sources of borehole to the point of use (households) and practices of water management.

Tracking	Villages	Sample	Microbiological			% variation in TC from source to household storage	Cl^- (mg/L)	NO_3^- (mg/L)	Treatment of water	Kind of treatment	Signalized hand washing	Soap sign	Proof of coverage	Signalized frequency of cleansing	Toilet type
			TC	E.coli	FC										
Augmentation	Zanabougou	Source 1(BH)	0	0	0		87.2	34.2							
		HPSV	0	0	0										
		Households storage	4	0	0	400%	79.7	30.1	Yes	tissue filtration	With detergent	No	No confirmation	When dirty	No toilet
Reduction	Benzana	Source 1(BH)	6	0	0		8.1	23.5							
		HPSV	6	2	0										
		Households storage	0	0	0	600%	9.1	19.4	No confirmation	No confirmation	No confirmation	No confirmation	No confirmation	No confirmation	No confirmation
	Koukoun	Source 1(BH)	4	3	0		7.7	17.6							
		HPSV	4	3	0										
		Households storage	0	0	0	400%	7.7	17.6	No	Not applicable	Water with wood-ash	No	Yes	every day	Pit latrine with slab
	Djigo	Source 2(BH)	2	0	0		7.4	13.8							
		HPSV	0	0	0										
		Households storage	0	0	0	200%	7.1	13.8	No	Not applicable	Water with wood-ash	No	Yes	every day	Pit latrine with slab
No change	Kolotomo	Source 1(BH)	1	2	0		8.2	23.5							
		HPSV	5	0	0										
		Households storage	1	0	0	0	7.5	23.5	No confirmation	No confirmation	No confirmation	No confirmation	Yes	No confirmation	Pit latrine with slab

Benzana	Source 1(BH)	3	1	0		6.8	20.2							
	HPSV	1	0	0										
	Households storage	3	0	0	0	5.3	19.7	No	Not applicable	With soap	Yes	Yes	every day	Pit latrine without slab
Banakoroni	Source 1(BH)	3	0	0		5.7	31.7							
	HPSV	0	1	0										
	Households storage	3	0	0	0	6.4	24.5	No	Not applicable	Water with wood-ash	No	Yes	When dirty	Pit latrine with slab
Pogo	Source 2(BH)	0	0	0		20.5	29.8							
	HPSV	6	3	0										
	Households storage	0	0	0	0	18.7	29.8	Yes	Sedimentatio n	With soap	No	Yes	every day	Pit latrine with slab
Tessereboougou	Source 2(BH)	2	0	0		11.6	30.6							
	HPSV	2	0	0										
	Households storage	2	0	0	0	12.0	30.4	No	Not applicable	With detergent	No	Yes	every day	Pit latrine without slab
Kani	Source 3(BH)	0	0	0		9.6	23.5							
	HPSV	14	2	2										
	Households storage	0	0	0	0	10.1	23.5	Yes	Aquatabs tables	With soap	Yes	Yes	every day	Pit latrine without slab

Possible sources of water-related contamination

Six hundred fifty-four (59.56%) of the respondents reported using improved water sources, of which 101 (15.44%) of those reportedly used protected dug wells. Indeed, it was seen that there were no dug wells among these wells that had the recommended sanitary characteristics and therefore should have been reported as not improved. While 784 (71.4%) of respondents hauled the water several kilometers themselves, 207 (18.85%) mentioned that they use more than 60 L per day per household. 418 (38.07%) of the participants reported that the last ten days prior to the study, their primary resource of water was not available for at least an entire day. Six hundred and eighty respondents (61.93%) responded they used unprotected (unimproved) sources at such moments. As to water handling and storage, it has been seen that an overwhelming 969 (88.25%) of respondents had separate the storage vessels for domestic use and drinking water purposes, and all of them covered their storage containers. Nine hundred and sixty-four respondent (87.8%) said that they used a small calabash with a handle to take water from the storage vessels. Five hundred and ninety-one respondents (53.83%) mentioned that they practiced home water treatment to purify their drinking water. The most common were tissue filtration treatment method 198 (18.03%), followed by sedimentation 109 (9.93%); chemical treatment by adding aquatabs tablets 82 (7.47%), by boiling 47 (4.28%) and other types of combined treatment.

Probable sources of contamination from sanitation-related Cognizance, Attitudes, and Practices

The results of the study indicated that 992 (90.35%) of respondents said using traditional means to dispose of excrement, of whom 907 (82.6%) used traditional pit latrines, and 81 (7.38%) used the bush (i.e., open defecation). Nevertheless, it was observed by the interviewers that 945 (86.07%) had an excrement disposal facility. As to feces management of children below the age of five years, a large part of respondents 878 (79.96%) were aware that the feces of children could be a source of contamination of drinking water. However, 900 (81.97%) declared throwing the feces of their children below the age of five years into the toilet. Only 441 (40.16%) declared washing their hands with water and soap. The surveyors have seen water for washing at the dedicated hand washing location in 280 (25.5%) households, and soap was observed at the designated hand washing location in only 272 (24.77%) of households. The other mentioned hand washing practices were washing with water and wood-ash 38 (3.46%), with water and detergent 49 (4.46%), and sand and water 66 (6.01%). Four hundred and fifty (40.16%) of study participants declared the minimum distance between a water source and toilet should be higher than 50 m.

In terms of toilet maintenance, 409 (37.25%) said cleaning their toilets once a day and 217 (19.76%) three times a week. This is consistent with investigators' findings (i.e., observations) that 715 households (65.12%) maintained toilets in a passable or suitable condition. As to the management of solid waste, 407 (37.07%) of study participants reported disposing of their waste in open landfills, 460 (41.89%) in a garbage pile near their household, 59 (5.37%) in ravine, 111(10.11%) burned their wastes.

DISCUSSION

The evaluation of the institutional and legislative framework for water quality surveillance at the regional and communal levels shows that implementation and compliance with national drinking water quality guidelines are inadequate for causes related to the lack of an organism legally responsible for monitoring labour, logistics, laboratory infrastructure, kit, and reactants. National, regional and local authorities need to fill the gaps emphasized in the study by strengthening institutional capacities and furnished the human, financial and material resources required to implement a system of continuous monitoring and surveillance of water quality at the local level.

The elevated pH content of the sample from HP, DW, and certain BH, as well as the elevated electrical conductivity content of overall samples from point of collection and point of use is worrying because of the potential reduction in the effectiveness of disinfection and the resulting inadmissible taste and odor. This may encourage consumers to look for unimproved sources and prone them to public health issues (i.e., waterborne diseases) (Onabolu et al. 2011). Turbid water could entirely be deemed as questionable. Additionally, problems linked with elevated levels of turbid water are more of an aesthetic problem, and also can have harmful effects on health (Amadou Toure et al 2018). Our study has shown that water samples from surface sources and storages were inappropriate for turbidity values. Levels of turbidity are a function of the number of suspended particles in the water. The particles of suspended serve as a substrate for microorganisms in water and favoring the growth of microbial populations. The augmentation of turbidity values (surface water) is a sign of pollution that increases the number of pathogenic microorganisms. Water with a high concentration of TDS may diminish water lucidity, thus supporting disease-causing microorganisms (Mary et al. 2017). The elevated TDS values can be as a ensue of pollution which likewise promotes the micro-organisms growth. The findings presented in this study showed that the chemical characteristics were almost within allowable limits, whereas the elevated TH content in certain of the samples is of worrying because of the economic costs of using more detergent or soap in laundry and the unpleasant taste of very hard water which forces consumers to depend on unsafe alternative sources (Mary et al. 2017). The elevated Mn contents obtained in all of the samples are significant because they give an unpleasant taste to drinking water. It is worth noting that certain investigations have confirmed a hazard of neurological troubles via inhalation with the brain as the principal target site (WHO 2008). Even more serious, it can cause persistent neurological troubles with symptoms almost identical to those of disease of Parkinson (Azizullah et al. 2011). The mediocre bacteriological quality of all point of collection (i.e., sources), in exception of boreholes, subject users to waterborne diseases. It should be noted that low counts of FC were revealed at the point of collections and households, as evidenced by low Cl^- and NO_3^- concentrations at collection points and at the household level. This can be attributed to the elevated number (86.07%) of toilets remarked and those declared by the respondents (82.6%) during the study.

The physico-chemical parameters did not change significantly when tracking from point of collection to point of use level; for example, the concentrations of NO_3^- and Cl^- remained almost unchanged. However, changes in microbial quality between the point of collection (source) and the point of use (household) have been noticed, but this did not augment under all contexts. On the one hand, there was a degradation, on the other hand, there was an amelioration and in plenty of cases, it stayed unchanged. The noticed augmentation in coliforms may mainly be due to unhygienic water handling, and sanitation problems, whereas the diminution can be attributed to the natural disappearance of bacteria. Interesting, there was no distinct trend between the treatment of water, hand washing with soap, coverage of water storage vessels and noticed quality of microbial. This might be as a result of the fact that hand washing and treatment of water have been self-declared and that treatment of water has not been validated by the surveyors. The results revealed a disparity between the use of soap as a self-declared practice by four hundred and forty-one respondents or 40.16% and the observation of soap by the interviewer at the designated hand washing location in 272 (24.44%) households.

The elevated number of TC of the dug wells (DW) may be attributed to the lack of sanitary characteristics seen in overall wells. However, it is necessary to involve the different village communities in the study area by training them in the construction of wells that meet international standards and in the maintenance of boreholes because Six hundred and eighty respondents or 61.93% declared using alternatives sources whenever their principal water source was non-operational (i.e., non-functional). It was found that 969 (88.25%) of the respondents had separated the storage vessels for domestic use and drinking water purposes, as well as the self-declaration of 964 respondents (87.8%) to use a small calabash to take water from the storage vessels are encouraging gestures that should be supported. These patterns could be the basis for the observed decrease of E-coli and FC counts at the point of collection and household level. Another reason for the low of E-coli and FC counts at the point of collection and at households level is the elevated number of self-declared traditional pit latrines 992 (90.35%) and 907 (82.6%) observed, as well as the low open defecation rates 81 (7.38%).

CONCLUSION

Based on the outcomes of this field study, it was noticed that the institutional framework for the implementation of the monitoring system in the Segou region of Mali is limited to a small number of setting types and need to be improved. The waters furnished at the point of collection (source) are not harmful to the wellbeing of the populace in relation to most of the physicochemical parameters, apart from the pH, EC, NO_3^-, TH, and Mn presenting health risk and consequences of economic. The physical and chemical characteristics consistency between the point of collection and point of consumption denotes that the control of chemical quality may be protected from point of collection to household level on the condition that the point of collection development is properly performed. Yet, the evolution of bacteriological quality proposes that it is important to properly develop the point of collection, protect, treat and store safely at the point of use i.e., household level. Although traditional latrines are deem supposed not improved, they were efficient for the management of waste discharged from the body (i.e., excrement) and this may be thanks to their cleanness as found in large part of households (65.12%). Yet, it is necessary to encourage the community to use traditional latrines in a hygienic way. The investigation aspects validation with interviewers observation and the proximity of the outcomes acquired from both sources point out that the investigation results are a faithful reflection of the areas studied. Evidence gathered through this investigation suggests that such studies validate water treatment demand by means of chlorine residuals analysis, observing treatment devices to ameliorate the capacity to associate water treatment and other practicals of water management with water quality of household. Despite the sector endeavor to ameliorate water quality management practices, there is a need to make sure that decision-makers be an awareness by furnishing them with visual and technical data in order to help them make informed decisions and allocate the necessary and sufficient funds.

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