Evaluation of Water Quality in Shallow Wells at Mokowe Village in Lamu County

Saidi S. Saidi[1*], Justin K. Maghanga[2], Paul M. Guyo[1]

[1] Pwani University, P. O. Box 195-80108, Kilifi, Kenya

[2] Taita-Taveta University, P. O. Box 635-80300, Voi, Kenya

*Corresponding Author: bakhalasaaid@gmail.com

ABSTRACT

Inadequate supply of fresh piped water at Mokowe Village in Lamu County has forced the residents to depend on alternative water sources such as shallow wells for their daily needs such as shallow wells. However, most of the wells are located near residential houses less than 30 m from the pit latrines. This closeness contaminates the aquifer that supplies water to the wells. Gastrointestinal infections are among the challenges experienced in Mokowe Village. This study investigated the quality of water in shallow wells at different times of the day. The objective of the study was to evaluate the physico-chemical parameters and microbial contamination of water from two main shallow wells, namely Salim Hassan and Baoni, with respect to their distance from the pit latrines. Water samples from Himwa tap was collected as a control. Total coliforms and *Escherichia coli* (*E.coli*) were analyzed by the most probable number (MPN) method. Physicochemical parameters analyzed were fluorides, nitrates, iron, sodium, potassium, pH, total dissolved solids (TDS), chloride, magnesium, calcium and total hardness, These were determined using DR 6000 Spectrophotometer, flame photometer, pH meter gravimetric analysis and wet methods (titration) respectively. Odour and taste were determined using organoleptic methods while colour was analyzed using a colour comparator. Total coliforms and *Escherichia coli* levels in the two wells were very high in the rainy season compared to dry season while Himwa tap water had no *E.coli*. However, total coliforms counts in Himwa tap water was beyond the permissible levels given by National Environment Management Authority (NEMA). Chloride, nitrate, sodium, potassium and calcium were beyond the allowable Maximum Contamination Level (MCL) provided by NEMA. Levels of pH for all the water samples were within the NEMA standards. The results indicate that water from the two main shallow wells were highly contaminated hence prompt chlorination and water quality monitoring should be undertaken. It was recommended that the public health office should ensure compliance on distance from the buildings when a new well is being constructed.

Keywords: *Shallow wells, Escherichia coli, Pit latrines, Physicochemical parameters, Microbial contamination*

INTRODUCTION

Mokowe Village is located in Hindi Ward, Lamu County. Lamu, is in the north coast of Kenya, borders Kilifi County in the southwest, Garissa County to the north, Republic of Somalia to the northeast and the Indian Ocean to the South (County Government of Lamu [CGL], 2018). In Mokowe Village, the residents have been experiencing difficulties in accessing clean water for drinking and other household needs. Water is one of the most vital basic needs that mankind has to be supplied with. In addition, water is important in many ways, such as, drinking, washing, transportation, chemical uses, heat exchange, fire extinction, recreation and in industrial applications such as; in the production of energy (e.g. hydroelectricity) and food processing among others (Department of Water Affairs and Forestry [DWAF], 1996). Water makes up 2/3 of human body composition; the human brain is made of 95% of water, blood 82% and lungs 90%. Therefore, without water human being can only survive for a few days (Sharma & Sanghi, 2012).

The inhabitants of Mokowe have been experiencing difficulties in accessing adequate clean water for drinking and other domestic needs, as a result the people of Mokowe Village have for a long time relied on the slightly salty water from shallow wells for their daily needs. According to the Lamu water and sewerage company (LAWASCO), inhabitants of Mokowe Village used to receive clean piped water from Amu Island. The project was initiated and managed by the Ministry of Water; however, follow-

ing revenue losses incurred, the supply of water to Mokowe Village was terminated. It was at this time that the residents of the village reverted to shallow Wells as the alternative source of water to meet their needs.

In the study area shallow wells are surrounded by households with inbuilt sanitation which are not so well designed; with poor and inadequate groundwater protection. The distance between the wells and the pit latrines is less than what is required in the Public Health regulations; this could lead to draining of latrine waste-water into the aquifer supplying water in shallow wells. Majority of disease causing organisms lack the property to propel themselves through the environment in which they live and those that can propel themselves are not capable of traveling very long distances. Instead, pathogens are carried from one point to another within the medium in which they live and in the case of pit latrines water transports the contamination into the aquifer and nearby wells.

The inhabitants complained of gastrointestinal infections since the situation exacerbated in 1997 when cholera struck the area and this compelled the Ministry of Public Health to treat the wells as many lives were lost. In 1998 the Ministry of water discovered a worthy water resource in Chomo, Hindi Ward, Lamu County to supply fresh clean water to the villages around, including Mokowe Village. This forestalled the demand by natives of these villages on shallow wells and other treated water sources. Since the discovery of the new source of water, the ministry relegated the priority of shallow wells and therefore they were unattended to by the Public Health officials.

The new water supply service didn't last beyond the year 2000 as a result of deterioration in the quality and quantity of water. This compelled the community in Mokowe to revert back to harvesting water from the shallow wells, which have hitherto become their only source of water. Shallow wells are therefore a very essential source of water in the study area despite the health risks that may emanate from them due to their close proximity to pit latrines. This study therefore, investigated the quality of water in shallow wells in Mokowe Village in Lamu County to determine its suitability for domestic use.

MATERIALS AND METHODS

The study was conducted at Mokowe Village in Lamu County during rainy and dry seasons; between August and September of 2015 and January and February of 2016 respectively. Mokowe Village is located at 2° 13' 52" South, 40° 51' 31" East and is 242 km from Mombasa. The predominant form of sanitation in the study area is the pit latrine. The area has a total of six (6) shallow wells which are surrounded by households and the study focused on two most used shallow wells which are the main source of water for the residents.

The study focused on two areas within Mokowe village namely Tumbo la Kati and Majengo where the two main shallow wells are located. One well is situated in Majengo area namely Kisima cha Salim Hassan, coordinates 2˚14'19.6"S, 40˚50'46.2' E, and the other in Tumbo la Kati area namely Kisima cha Baoni, coordinates 2˚14'17.4"S, 40˚50'50.5"E. The choice of the sites was based on the high population that obtains water from these wells for domestic use.

Sampling bottles and tools were sterilized using an autoclave. The study employed purposive sampling, to select the shallow wells for sampling. Two wells were selected namely Salim Hassan and Baoni, these are the only wells used by the community living in Mokowe Village owing to less salinity compared to the rest, which are highly saline and unused.

The study employed both qualitative and quantitative methods. For quantitative method samples were obtained from the shallow wells using a conventional method by the community (a rope tied to a rope). Sampling was carried out three times during the rainy season in August to September 2015, and three times during the dry season in January-February 2016. A total of 50 samples were collected during rainy and dry seasons. Two samples (one for physicochemical and another for microbial tests) were collected from the two most used shallow wells. Samples were collected in the morning at 4 am before the community commenced their daily chores of drawing water from the wells. Two samples were collected after the day activities at 8 pm hence making up a total of eight samples per visit. Water from Himwa tap was

collected for comparison (control). The samples were collected in sterilized, sealed and labeled 1L polyethylene bottles for analysis.

The average distance of pit latrines to shallow wells was also measured. Questionnaires were employed as the main data collection instruments for qualitative method. A conventional formula of 10% was used to obtain the size of the sample (sub group). The study applied simple random sampling procedures to obtain the respondents for questionnaires without bias. A total of 225 (10% of households) questionnaires were administered to the residents of Mokowe in October 2015. Three enumerators were hired and trained on how to collect data via questionnaires over 45 day duration.

The physicochemical parameters and microbial levels in the sampled water were tested and analyzed using standard methods and procedures at the Government Chemist Laboratories in Mombasa. Total coliform and *E. coli* were analyzed by most probable number (MPN) method while physicochemical parameters such as fluoride and iron were analyzed using the DR 6000 Spectrophotometer, sodium and potassium were analyzed using flame photometer, pH was measured using pH meter, nitrates amount was determined by DR 6000 Spectrophotometer and chloride, magnesium, calcium and total hardness were analyzed by wet methods (titration). Two-Sample T-Test and Mann-Whitney Test were used to compare the physicochemical and microbial loads between the short rains and dry seasons respectively. Wilcoxon Signed Rank Test and Paired T-test were also used to show disparity between the sampling times (8 pm and 4 am) per visit during short rain and dry season.

RESULTS AND DISCUSSION

The microbial analysis indicates the water in the two wells was highly contaminated with Total Coliforms and *E. coli* (Table 1). The levels of total coliforms were above the NEMA recommended values. However, Himwa sample had *E. coli* within the recommended levels while total coliforms were beyond the allowable limits.

The rainy season did not have a significant change in the Total Coliforms in the two wells at the different sampling times of the day. However, in the dry season, *E. coli* levels were relatively lower than in the wet season. This could be attributed to surface runoff during wet spells that increases pollution into the existing wells as well as transport of faecal materials form the pit latrines.

Table 1: Microbial analysis of water samples

			RAINY SEASON		DRY SEASON	
Site	**Visit**	**Time**	**T. coliform**	***E. coli***	**T. coliform MPN/100 mL**	***E. coli.* MPN/100 mL**
Salim Hassan well	1	8:00pm	>2400	>2400	>2300	220
Salim Hassan well		4:00am	>2400	>2400	1700	18
Salim Hassan well	2	8:00pm	>2400	>2400	1700	36
Salim Hassan well		4:00am	>2400	1100	1700	18
Salim Hassan well	3	8:00pm	>2400	93	2300	220
Salim Hassan well		4:00am	240	240	1700	42
Baoni well	1	8:00pm	>2400	>2400	>1300	130
Baoni well		4:00am	>2400	>2400	>2400	14
Baoni well	2	8:00pm	>2400	>2400	1700	9
Baoni well		4:00am	>2400	1100	2300	0
Baoni well	3	8:00pm	>2400	>2400	>2400	130
Baoni well		4:00am	>2400	>2400	>2400	18
Himwa Tap			1100	0	1100	0
NEMA maximum contamination level (MCL)			10	0	10	0

In the rainy season, total coliforms ranged from highest value of >2400 MPN/100 mL to lowest value of 240 MPN/100 mL recorded in the third sampling in September at Salim Hassan Well. These levels were

clearly beyond the maximum contamination levels of 10 MPN/100 mL recommended (NEMA, 2006). Whilst, the total Coliforms for dry season ranged from 1300 to > 2300; these were beyond the maximum contamination levels recommended by NEMA of 10 MPN/100 mL.

E. coli levels in the two wells during rainy season ranged from 93 to > 2400 MPN/100 mL, while for dry season they ranged from 0 to 220 MPN/100 mL. Nevertheless, Baoni Well visit 2 at 4:00 am indicated no *E. coli*, whereas the rest were beyond the maximum contamination level (MCL). Total coliforms in Himwa tap water were 1100 MPN/100 mL which is beyond the recommended levels while *E. coli* level was nil. In the rainy season, both Total coliforms and *E. coli* levels in the two wells were very high compared to the dry season. The smaller the amount of water in the pit latrines, therefore, the lower the risk of water point contamination (Sugden, 2006). The larger the number of users, the higher the amount of water drawn from a well and the higher the hydraulic gradient between the well and the latrine, consequently the higher rate of flow to the well and hence more contamination (Kiptum & Ndambuki, 2012).

Total coliforms and *E. coli* are used as indicators of possible sewage contamination because they are commonly found in human feaces. Therefore, their presence in the sampled water from the selected wells suggests that pathogenic micro-organisms might also be present and consumption of water from these sources might pose a severe health risk (Abdulkadir *et al*, 2015).

The outcome of the physicochemical analysis for both rainy and dry seasons (Table 2) was compared to the acceptable levels designed by NEMA to indicate the suitability of water from Baoni and Salim wells. Odour of samples from both wells in both rainy and dry seasons were earthy-musty. This was attributed to natural biological process compared to Himwa tap water which was odourless. Water from the two wells had a sour taste compared to Himwa tap water which was sweet. The water samples were colourless during rainy season and turbid during dry season. Turbidity in the dry season was attributed to low water levels in the two wells as bucket use to draw the water from the well unsettled water leading to turbidity while Himwa water was colourless. The pH values of all the water samples ranged from 7.20 to 7.82 which were within the NEMA standards. Sodium levels ranged from 714 to 220 mg/L that exceeded the (NEMA, 2006) standard guideline of 200 mg/L.

Fluoride values for both wells during rainy and dry seasons ranged from 0 to1.27 mg/L these were below the standard limit of 1.5 mg/L while Himwa water had 1.2 mg/L. Nitrate levels during both rainy and dry seasons ranged from 0 to 32 mg/L. However in Baoni and Salim Hassan visit 1 at 8 pm and visit 3 at both 8 pm and 4 am respectively during the rainy season, Nitrate levels were beyond the MCL. Similarly nitrate levels of the water sample from Salim Hassan Well visit 1 at 4 am, visit 2 and 3 at 8 pm during the dry season were beyond the MCL. Baoni Well visit 1, 2 and 3 at both 8 pm and 4 am for the dry season had nitrate levels beyond the MCL (Max limit of 10 mg/L). Himwa water had nitrate levels beyond the maximum allowable limits. Mg values were below the permissible level of 6.72-36.2 mg/L (Max limit of 100 mg/L). Chloride and potassium values 450 to 660 mg/L and 280 to 480 mg/L respectively of the two shallow wells were beyond the limits of 200 mg/L Cl and of 100 mg/L K compared to Himwa tap water with potassium and chloride levels fell within the maximum allowable limits.

The total hardness values ranged from 330 to 544 mg/L which exceeded the limit of 300 mg/L compared to Himwa tap with 280 mg/L which was within permissible levels. The total dissolved solids of all the samples ranged from 1800-3800 mg/L and exceeded the MCL of 1200 mg/L. However, Fe levels from all the samples ranged from 0-0.1 mg/L which is below the NEMA limits of 0.3 mg/L (NEMA, 2006). Calcium level of Baoni Well visit 2 at 8 pm, Salim Hassan Well visit 1 and 3 at 8 pm, visit 2 at 8 pm and 4 am during the rainy season were beyond the MCL. Similar trend was seen in Baoni visit 1, 2 and 3 and Salim Hassan visit 1, 2 and 3 at 4 am in the dry season, respectively. Calcium values in both rainy and dry seasons for Himwa water were below the limits (150 mg/L). Two-sample t-test and Mann-Whitney test were employed to show comparison between rainy and dry seasons. However, the

Table 2: - Physiochemical parameters of samples collected from Salim Hassan and Baoni Wells for both rainy and dry seasons.

Parameters	Maximum Limit by NEMA	Time	WELLS PER VISIT DURING RAINY SEASON						WELLS PER VISIT DURING DRY SEASON						Himwa Tap
			Baoni			Salim Hassan			Baoni			Salim Hassan			
			1	2	3	1	2	3	1	2	3	1	2	3	
Sodium	200(mg/L)	8 pm	872	860	720	1120	1220	1160	722	720	720	1200	1200	1210	350
		4 am	740	740	714	1220	1160	1100	840	842	840	1180	1182	1180	
Fluoride	1.5(mg/L)	8 pm	1.22	1.27	0.8	0.7	1.21	0.8	0.72	0.68	0.70	0.84	0.88	0.82	1.2
		4 am	0.78	0	0.66	0.83	0.66	0.82	1.26	1.24	1.26	0.7	0.8	0.7	
Nitrates	10(mg/L)	8 pm	14	0	20	12	1.2	12	16	14	18	10	12	12	22
		4 am	0	1.4	32	0	1.1	11	22	20	22	12	10	10	
Chloride	240(mg/L)	8 pm	660	540	450	620	640	580	460	462	462	650	652	653	200
		4 am	480	452	540	656	596	652	550	550	550	590	590	590	
Potassium	100(mg/L)	8 pm	472	360	280	452	480	456	280	280	280	398	398	398	55
		4 am	300	300	340	480	460	430	350	352	352	462	460	460	
Magnesium	100(mg/L)	8 pm	36.2	29.76	8.5	12.4	8.64	16.2	6.42	6.42	6.42	34.2	34.2	34.2	7.5
		4 am	6.72	8.64	8.22	35.52	17.28	32.4	30.2	30.0	30.0	16.4	16.2	16.2	
Calcium	150(mg/L)	8 pm	134.2	168	120.2	174.4	174.4	162.2	120	122	122	130.8	130	130	82
		4 am	120	118.4	118.2	132.8	163.2	142.4	170	170	170	160.0	160.2	160	
pH	6.5-8.5	8 pm	7.62	7.57	7.62	7.56	7.52	7.58	7.4	7.4	7.4	7.6	7.2	7.4	7.2
		4 am	7.72	7.53	7.82	7.61	7.59	7.4	7.48	7.46	7.4	7.4	7.4	7.2	
Total Hardness	300(mg/L)	8 pm	482	544	330	462	472	482	330	332	332	448	450	452	280
		4 am	328	332	340	480	480	402	550	550	550	462	460	462	
TDS	1200(mg/L)	8 pm	3200	2700	2200	3300	3300	3120	2450	2450	3100	3120	3120	3120	1800
		4 am	2300	2200	2600	3180	3200	3200	2800	2800	3820	3300	3400	3300	
Iron	0.3(mg/L)	8 pm	0.01	0.01	0.02	0	0	0	0.01	0.01	0.01	0.1	0.1	0.1	0.01
		4 am	0.05	0.01	0.05	0.01	0	0.02	0.01	0.01	0.01	0.01	0.01	0.01	

outcomes were not responding since P-values (significant levels) were beyond 0.05. Average levels were used to show comparison and it was apparent that the rainy season had the highest concentration of Physicochemical parameters compared to the dry season since mean and median levels, revealed by both Two sample t-test and Mann Whitney, respectively, showed that the rainy season was high compared to the dry season.

Results obtained from the administered questionnaire on main source of water are represented in figure 1 below. A total of 91% of the respondents used well water as their major source of domestic water, since tap water was not reliable. Majority of the villagers live below the poverty lines and cannot afford to buy water from the nearby village, thus inclining on shallow wells some of which are uncovered at the top. However, 9% said they used tap water to alleviate their needs; they are middle class and said to have been buying water from the nearby Village (Hindi). None were using boreholes or reservoir (Figure 1).

Figure 2 shows the results collected from the respondents in terms of their awareness of the safety of the water. Most respondents (67%) reported to having used water from the wells. These respondents considered the water to be safe for consumption due to numerous efforts made by public health officers to lessen the contamination. Among the efforts they recalled were taking care of the wells in case of an outbreak in the neighboring village and by engaging the villagers through community health workers, distribution of chlorine tablets in households and training households on how to use the tablets. However, 32% reported that the quality of the water was not safe and 1% did not respond. The distance between the pit latrines and the two wells was 11m; which is less than half, the recommended distance.

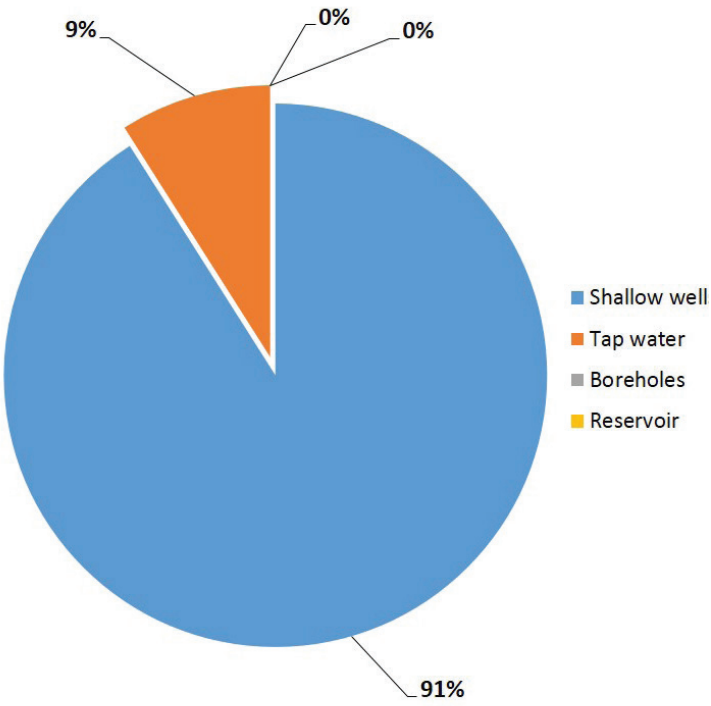

Fig. 1: Sources of water

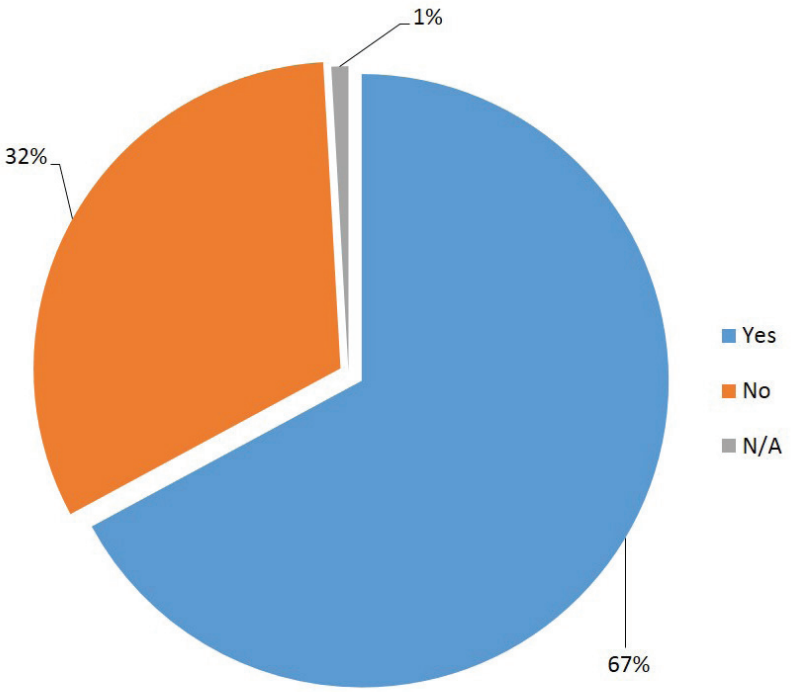

Fig. 2: Safety of water in the shallow wells.

CONCLUSIONS AND RECOMMENDATIONS

The results showed that 91% of the respondents used shallow wells as their main source of domestic water. The findings show that the water from the two main shallow wells was not safe for consumption due to the high levels of microbial contamination and physicochemical parameters. Fluoride, magnesium and iron levels were below the acceptable limits by NEMA while the remaining parameters were beyond the limits for portable water standards.

Himwa water was also not safe for drinking owing to high levels of total coliform which was beyond the permissible levels. Most of the physicochemical parameters were within the acceptable limits except for sodium and nitrate, which were beyond the recommended limit, this can be amended by addition of coagulant such as alum.

The Public Health Officers should enforce set procedures for sinking wells and enhance awareness through enlightenment campaign on the danger of digging shallow wells close to pit latrines. The County Government of Lamu should ensure adequate and efficient public water supply through the provision of piped water.

Treatment of water should be recommended before use and more water sources should be created to avoid enormous pressure on the two main shallow wells which has led to drying of the wells.

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