Sanitary Survey of Shallow Wells within Farms in Ainabkoi Sub-County, UASIN Gishu County Kenya

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ABSTRACT

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Keywords: farm sizes, groundwater, seasons; contamination risk; sanitary survey.

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Keywords: farm sizes, groundwater, seasons; contamination risk; sanitary survey.

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I. INTRODUCTION

Groundwater is the main source of domestic water supply for the community of Ainabkoi Sub-County and is exploited through shallow wells (Uasin Gishu Integrated Development Plan (UGCIDP), 2013). Groundwater is considered to be more stable in quality, is conveniently available and accessible for the family and wells can be developed at comparatively low costs. However drinking water quality is of major concern in developing countries with regard to microbiological, inorganic contaminants and physico-chemical properties which deteriorate water quality (Sorlini et al., 2003). Communities should have access to safe drinking water as a basic need for health and sustainable development as outlined in the sustainable development goals (SDGs) which focus on ensuring universal and equitable accessibility of

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safe water for all by 2030 (6th SDG) (Osborn et al., 2015).

Under natural conditions, fresh water in shallow aquifers has a relatively short residence time, and its chemistry remains practically unchanged under the effect of a set of natural influences such as physical, geographical, geological and hydro-geological factors. However human economic activities can distort this natural balance (Rutkoviene, Kusta, and Èesoniene, 2005). Well characteristics such as well depth, well age, type of well and its structural features, distance from vegetable gardens, and slope of the land, have been found to contribute to the level of pollution in the groundwater (Bruggeman *et al.*, 1995).

Groundwater may become contaminated naturally or from numerous types of anthropogenic activities within the vicinity of the well, as well as inappropriate well construction (Fawcett, 1992). Thus, a poorly organized environment around the homestead, with poultry and livestock kept near the well will have an impact on the pollution of the water of shallow wells. According to Kutra, Kusta, & Rutkoviene, (2002) the distance at which the household premises, the cowsheds, greenhouses, vegetable gardens, pit latrines, dumps and other aggressive sources of pollution can be located and still have an impact on well water quality is 145 meters (Kutra *et al.* 2002). Animal wastes from active or abandoned feedlots may be a significant source of nitrates to groundwater (Kirder, 1987). When manure is stored in open lots for eight months, 7% nitrogen, 14% phosphorus and potassium enter the environment in the form of leachate, resulting in groundwater pollution from the leachate greatly exceeding the maximum allowable concentrations for the area (Kirder, 1987). The direction of groundwater flow also has an important influence on the probability of contamination. A widely-held tenet of groundwater hydrology states that water flows downslope along the gradient of the groundwater surface or water table (Rutkoviene, *et al.*, 2005). This gradient generally conforms to the surface contours. Thus, water quality in wells is highly influenced by pollutants moving from up-slope in the vicinity of the well (Rutkoviene, *et al.*, 2005). Therefore, an insufficiently dimensioned sanitary zone or a surface incline towards the well can lead to seeping of the surface water down into the well.

Groundwater contamination can be as a result of poor sanitation and subsequent leaching from the site especially in the vicinity of the well (Abdulsalam and Zubairu, 2013). In view of this a sanitary surveillance method was developed by Lloyd and Helmer (1991) to assess the drinking water quality and the associated risks or hazards in the water supplies in rural areas. A sanitary survey refers to an evaluation and on-site inspection of the physical environment of the water source to identify possible sources of environmental contamination (USEPA, 1999). Sanitary survey can be a complex technical task which involves inspection and the use of questions to assess the key elements of a water source itself, sources of contaminants and water handling (Lloyd and Helmer 1991 and USEPA, 1999). An inspection format developed by Lloyd and Helmer, (1991) consists of a set of questions that have 'yes' or 'no' answers. The questions are structured such that a 'yes' response indicates that there is reasonable risk of contamination and a 'no' indicates that the risk is negligible. A 'yes' response scores one point and a no scores zero points. Upon completion of the inspection, the points are summed up to give a sanitary risk inspection risk score which is referred to as the Contamination Risk Score (CRS) in this study. A higher CRS indicated a greater risk of well contamination by faecal pollution from the immediate surroundings of the well. The information generated by a sanitary survey helps identify existing and potential sanitary risks to the water quality. A sanitary survey systematically lists every fault in the system as a sanitary risk factor (Lloyd and Bartram, 1991).

Point sources of pollution are those where the origin of contamination can be identified such as localized agricultural practices that affect aquifers directly below the site (feedlots), septic tanks and landfills (Bolger and Stevens, 1999). Sources of pollution in groundwater may include runoff or seepage from fertilized agricultural lands, municipal and industrial waste water, refuse dumps, animal feedlots, septic tanks and private sewage disposal systems, urban drainage and decaying plant debris (Hudak, 1999 and Nas and Berktay, 2006). Non-point source pollution from agricultural activities such as animal farming and pit latrines have been reported to degrade groundwater quality and thereby threaten people's health. The use of poorly protected groundwater sources has been linked to acute diarrhoea in developing countries (Nasinyama, 2000).

The study was carried out within Ainabkoi Sub-County of Uasin Gishu County in Kenya, where shallow hand dug wells are the main source of water for domestic use. These hand-dug wells are constructed manually as irregular holes in the ground that intersect the water table and are prone to pollution from several sources (Todd, 1980). The wells may be exposed to pollution from surface run-off, poor sanitation in the vicinity of the well, effluent discharge from agricultural production activities and by the specific physical attributes of well construction. Mixed farming agriculture (food/commercial crops and livestock-dairy) characterized by different farm sizes is the predominant economic activity for the rural community of Ainabkoi Sub-County with farmers gradually shifting to intensive horticultural farming (UGCIDP, 2013). According to Goswami et al., (2014), the selection of factors that define farm typology varies greatly from study to study and may be governed by the purpose of research. For purposes of this study different farm sizes were determined as a working farm typology because it captured common characteristics within farms in each ward in Ainabkoi Sub-County. Therefore, farms in Ainabkoi, Kipsinende and Olare wards were classified as large, medium and small farm sizes respectively. Groundwater is the main source of water for drinking and other domestic needs in Ainabkoi Sub-County. Therefore, the aim of this project was to identify and assess the sanitary risk factors associated with the wells and subsequently determine the contamination risk score (CRS) as predictors of water quality.

II. METHODOLOGY

The study was conducted in 2012 and 2013 in three wards within Ainabkoi sub-county namely Ainabkoi, Olare and Kaptagat (Kipsinende) which have extensive agricultural activities. A baseline reconnaissance farm survey found that farmers predominantly practiced mixed farming whereby they grew maize, kept some farm animals, and had a variety of vegetables and fruit crops in small gardens beside their homes. However, each farm had its own unique characteristics with regard to the farm sizes, number and types of domestic animals kept, the maize acreage, variety of vegetable and fruit crops grown, and the homestead/property development such as landscaping, housing, toilet construction, well ownership and construction.

A conceptualized working typology therefore identified farms in Ainabkoi ward as mainly large, family-generations-owned mixed farming size and ranged more than 40 acres in size (>40 acres) with privately owned wells. In Kipsinende ward, farms were medium sized (10-40 acres) mixed farming size with privately owned wells. The farms in Olare ward were small mixed farm size which ranged 2-10 acres in size and with communally owned wells. Purposive random sampling technique was applied in selection of the representative farms within each ward whereby only accessible farms that had access to a well for evaluation of the groundwater sources were selected. For each farm size, Large mixed, Medium mixed or Small mixed farm systems, five farms were purposively selected such that each had access to a well within the farm or a centrally communal well.

2.1 Survey and Assessment of wells in relation to Sanitary risk factors.

Onsite sanitary survey of the wells and the homesteads was carried out in each farm in order to identify significant potential deficiencies, which could explain possible trends in the water quality with regard to the integrity of the whole system (USEPA, 1999). Observations and interviews were used to collect information on the sanitary aspects of the wells. Visual inspection and observations of the wells and the immediate environments were conducted on each farm in the different farm sizes. For the purpose of the study, the sanitary survey encompassed the essential components of water source as described in the sanitary survey assessment form adapted from Lloyd and Helmer (1991) and modified in the context of the observations specific to the study area. Visual examination of each well at the time of groundwater sampling was done along with interviews with the landowner. Interviews were used to determine land ownership, well ownership and age, ward of septic tanks, toilets and cowshed. During the survey, farm owners ascertained their land/farm management practices which included the stock of animal farms and water use.

The field and well inspections were carried out to find out the proximity of the wells to latrines and other sources of pollution, nature of well surrounding, well construction such as lining of the well (parapet), and mode of water withdrawal. A positive response indicated the presence of a risk and a score was allocated for a positive answer and no score for a negative answer. The positive answer scores were added up to give an overall sanitary contamination risk score.

The Contamination Risk Score (CRS) was as follows:

i. Very High Risk (VHR) = 9-11
ii. High Risk (HR) = 6-8
iii. Intermediate Risk (IR) = 3-5
iv. Low Risk (LR) = 0-2

The average CRS was determined for the wells within each farm system. The average percentage of wells within each farm size that were exposed to each of the sanitary risk factors was determined.

2.2 Description of the Risk Assessment Factors

In the context of the study area there were 11 sanitary risk factors (SRF) used to assess the quality of the well water and were modified and described as follows:

1. Distance of Pit latrine from well. The question aimed at determining if the well was located at a safe distance from contamination by the pit-latrine. In this case a 10 m distance was used as a general guideline value. It was common for the homesteads to have a pit latrine near the main house and may therefore be near the well.
2. Position of Pit latrine on higher ground in relation to the well.
   The observation question was based on the assumption that water flows downwards and hence the potential to contaminate wells downhill because the land was generally undulating.
3. Is there any source(s) of possible pollution (man-made attributes, animal excreta, rubbish, Septic tanks, constructions, feedlot runoffs, cowshed runoffs) within 10m of the well?
   The aim of this question was to check for any sources of pollution that may wash into the well. It was common for animals to be tethered and graze within the well vicinity where green grass was common. Some cowsheds/barnyards were not far from the well. Disposal of rubbish is done within the homestead.
4. Well Ownership: Wells were either privately or communally owned. This question focused on the assumption that communally owned wells may not be as well managed and protected like the privately owned one.
5. Was the well depth less than 15ft? This question was adapted because of the varied well depth in the different farm sizes. Deeper wells may indicate a lower water table and hence less likely to be polluted through leaching.
6. Does the general land terrain slope towards the well? This was an observation question of the land terrain to determine if it slopes towards the well. This was deemed important in sanitary risk determination because undulating land enhanced the likelihood of storm runoff into the well.
7. Do animals graze and water in the well vicinity? Livestock such as sheep were tethered and watered within a 10 m radius of

the well vicinity. The excreta from these animals can be a source of nitrogen pollution of the wells.

8. Is the water extracted by use of a bucket and rope?
   This question was based on the probability of well water pollution when buckets and ropes left in unsanitary positions such as lying on the well surface or grounds around the well. This question was aimed at determining if the water abstraction means were left in such conditions that they contaminated or polluted the water source. Water extraction from wells was done manually by use of a metal or plastic container which was tied to a rope for deep wells. However some wells had a windmill, and hand pumps which were used for water extraction.
9. Is the well open (not constructed)? Wells either had a wall (parapet) constructed around them or not. Wells that were at the same level as the ground were deemed susceptible to pollution from runoff and other sources of pollution.
10. Is there a likelihood of runoff entering the well? Runoff possibility into the well could be due to a wall (parapet) around the well that was not adequately high (more than 1m high) and other preferential pathways for the runoff to enter the well such as cracks on the wall. This observation question was aimed at determining if there was a wall (parapet) around the well that was adequately high (more than 1m high) to prevent surface water flow from entering the well?
11. Is the maize garden less than 5m from the well? The question assumed the likelihood of groundwater pollution through leaching of fertilizer N into groundwater.

III. DATA ANALYSIS

The data collected was subjected to the analysis of variance using SAS statistical package Version 6.12, (1997). ANOVA was done to determine if there were any significant differences between the farm sizes in the overall CRS and mean values were compared by least significant difference (LSD) at the 5% level.

IV. RESULTS

The results of the sanitary risk conditions of the wells in the different farm sizes in Ainabkoi ward are presented in Table 1. The sanitary survey revealed that there were highly significant differences between the farm sizes in the sanitary contamination risk scores. The homesteads within the large and medium farm sizes were well organized and landscaped whereby farm areas were subdivided into functional areas. These functional areas included grazing paddocks, the main house and homestead area, kitchen garden area, recreation/relaxing areas and utility areas. The wells within the large farm sizes were privately owned, 30-40ft in depth and were either protected from runoff by a raised construction (parapet) or semi-protected with a concrete wall that was close to the ground surface and covered with iron sheets (Figs. 1 to 3).

The medium-sized farm sizes were well planned, organised and landscaped with modern houses. Functional areas, grazing paddocks, cow sheds and utility areas such as the toilets were located in the backhouse and screened with live fences. The wells within the medium farm sizes had both protected and semi-protected constructions around the well (Figs. 4 to 7). Kaptagat ward, where the medium sized farms were located was generally flat with gentle slopes in some parts hence pollution from runoff may not be a common occurrence.

Most of the farms and homesteads within the small farm size, were not well planned. The houses were mostly semi-permanent and ranged from one house to about six houses within the homesteads. Wells within the small farm sizes were communally owned, shallow and unprotected making them vulnerable to pollution from runoff (Fig. 8-12). Water extraction from the wells was done by use of hand buckets and cans because the water wells were very shallow and the water level was always high. Within the small farm sizes, the general terrain sloped towards the wells and livestock were tethered to graze and were also watered in the well vicinity. This consequently littered the area around the well with animal excreta (Fig. 9).

It was apparent that the water table in the region of the small mixed farm sizes of Olare ward was mostly high and therefore the wells were shallow and remained full throughout the wet and dry season (Fig. 6). These wells were located at the bottom of the terrains or slopes which facilitated drainage and runoff down slope into the wells. Observation of the maize crop around the area around the well showed significant N fertilizer deficiency as shown in Fig. 7.

Table 1: Sanitary Risk Factors (SRF) observed in wells in the different Farm sizes in Ainabkoi Sub-County

Percentage of wells exposed to the sanitary Contamination Risk Factors				
Sanitary Risk Factors (SRF)		Farm sizes		
		Large	Medium	Small
		Percentage observed		
1	Latrine within 10m of well	33	20	60
2	Latrine on higher ground than well	0	100	80
3	Any other source of possible pollution (animal excreta, rubbish, fertilizer)?	67	40	100
4	Is the well communally owned?	0	20	100
5	Is the well less than 15ft?	0	40	80
6	Does the general land terrain slope towards the well?	100	40	100
7	Is the well vicinity livestock grazing ground?	33	20	100
8	Is the water extracted by bucket and rope?	66	60	100
9	Is the well open (Not constructed)?	0	40	80
10	Is there likelihood of runoff entering the well	66	60	100
11	Is the garden less than 5m from the well?	33	80	80
	Average of Sanitary Risk Factors(out of 11)	4.0	4.2	9.65
	*Contamination Risk Score (CRS) Range	IR (36%)	IR (38%)	VHR (87%)
	Significance (p=0.05))	***		
	Least Significant Difference (LSD)	0.148		

Adapted and modified from Lloyd and Helmer (1991)
*Contamination Risk Score Range: 9-11 = Very High Risk (VHR); 6-8 = High Risk (HR); 3-5 = Intermediate Risk (IR); 0-2 = Low Risk (LR).
*** Highly significant at $p \leq 0.05$.

Figure 1: A protected well (parapet) with a hand-manipulated water extractor

Figure 2: Semi-protected well showing the laundry activities and vegetable garden within the well vicinity a Large Farm Size

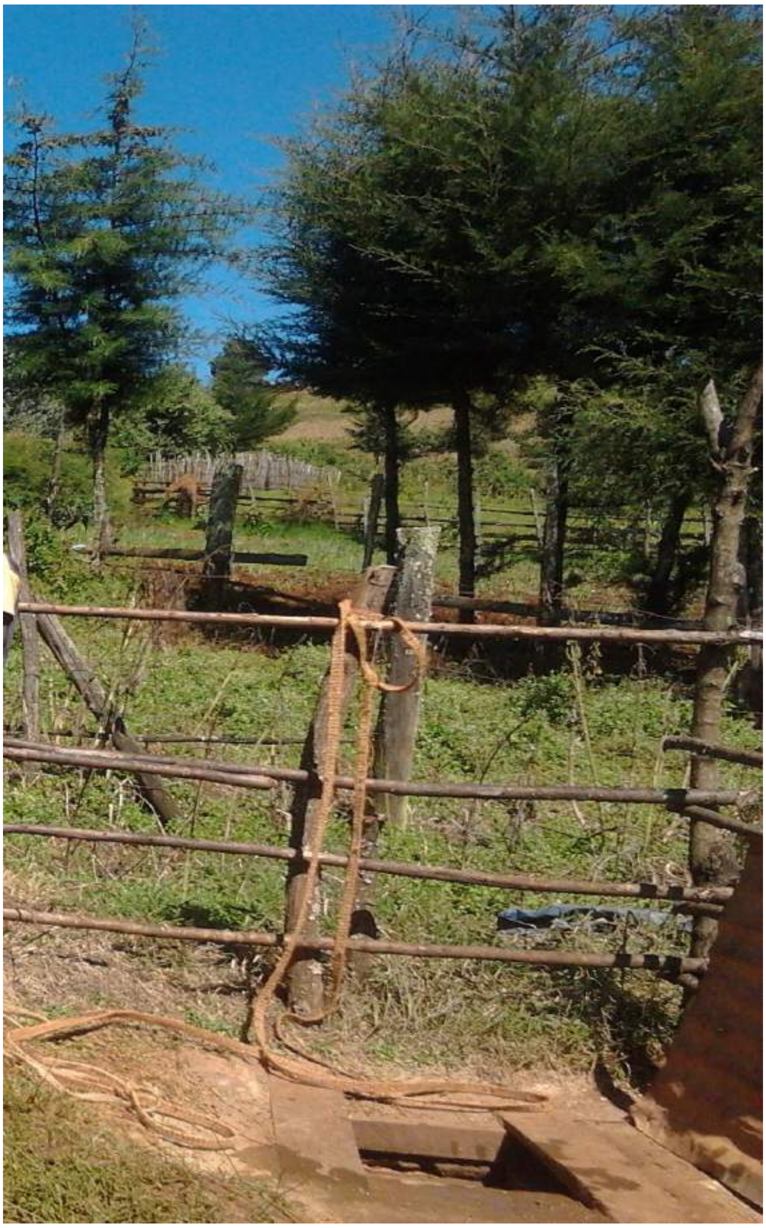

Figure 3: Close up of the semi-protected well in Fig. 2

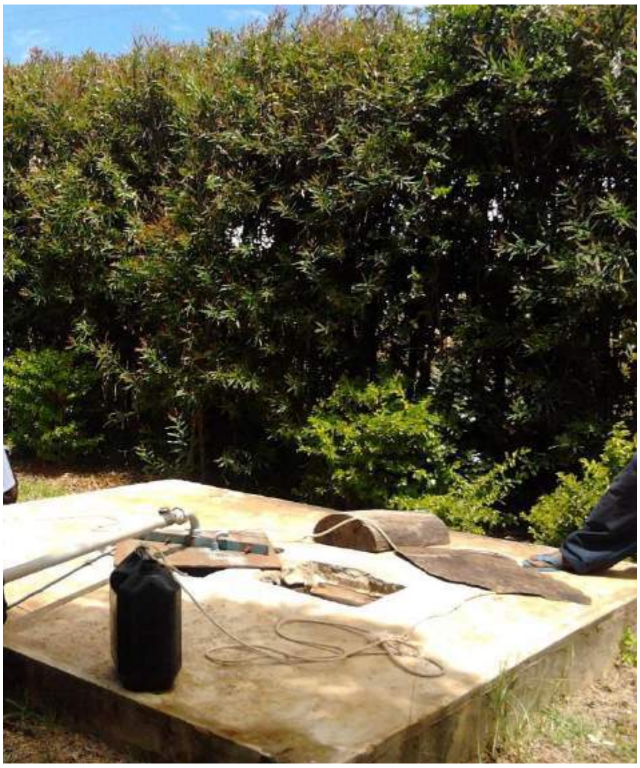

Figure 4: Protected well within a medium farm size showing modes of water extraction using a bucket and rope

Figure 5: Protected wells within the medium farm sizes showing windmill mode of water extraction

Figure 6: Semi-protected wells within the medium farm system surrounded by a vegetable garden

Figure 7: Semi-protected wells within the medium farm system surrounded by maize production in the vicinity of the well

Figure 8: A shallow unprotected communal wells used for both home water consumption and also for watering cattle in the small mixed farm size

Figure 9: A communal shallow well within the small farm system showing livestock grazing (left) and cow dung (right) within the vicinity of the well

Figure 10: A communal shallow well within the small farm system showing livestock waiting for water and cow dung within the vicinity of the well

Figure 11: In a small mixed farm in Olare ward showing the visibly high water table (right)

Figure 12: The road to a communal well in the small mixed farm system shows common N deficiency symptoms on the maize crop on the right

V. DISCUSSION

The results showed that farm characteristics can influence the SRF associated with individual wells and consequently the CRS. The differences in well contamination risk in the different farm sizes could have been due to individual farm endowments and ownership of the wells. In the large and medium farm sizes wells were privately owned and therefore it was apparent that efforts were made to maintain the sanitary standards of the well. However, wells within the small farm sizes were 100% communally owned and this may have contributed to the degradation of the area within the vicinity of the wells because the well was communally accessed by more people. This indicated that the people were either ignorant of the dangers associated with SRF or that the people/community could not control the use of communal property. The high percentage of wells located in positions where they are prone to pollution from the vicinity signifies that the well sanitary risk was not of importance in the choice of its ward. Similar results were reported by Abdulsalam and Zubairu, (2013) who reported that 80% of the wells were within 10m of the latrines and 70% were very close to the source of pollution indicating the indiscriminate positioning of wells in relation to sanitary risk.

The raised construction on the wells reduced the likelihood of contamination from pollutants in the well vicinity however the semi-protected wells were subject to runoff such as during the rainy season even though they had lid covers that helped reduce entry of surface flow of water into the well. The fact that the wells were not protected and that the terrain slopes towards the wells were major predisposing factors to the sanitary risks of the wells. The Large and Medium mixed farm size wells have an Intermediate Contamination Risk Score because most wells are protected and homesteads were moderately organized such that the well vicinity was relatively clean. This concurs with results by Llopis-Gonzalez, Sanchez, Marti-Requena & Suarez-Varela, (2014) who reported significant differences between percentages of protected and unprotected wells with regard to risk factors.

The wells within the small farm sizes were shallow due to the high-water table within the area of Olare unlike the low water table found in the large and medium farm system areas of Ainabkoi and Kaptagat. Llopis-Gonzallez *et al.*, (2014), also reported that the depths of wells at high risk of contamination ranged from 0 to 300m and therefore making deeper wells have an increased ability to filter contaminants through different soil layers. Kibona, Mkoma, & Mjemah, (2011) observed a decrease in nitrates with increase in well depth, with high nitrate concentrations occurring mainly in wells with depths less than 41m. They attributed it to anoxic conditions in the deeper wells where the oxygen levels are depleted and reduction of other electron acceptors such as NO_3^- become energetically favorable. According to Hallberg (1989), groundwater nitrate contamination is often detected in aquifers less than 30m deep because the major nitrate sources occur at the surface and there is a delay in the migration of nitrates

It was observed that wells within the small mixed farm sizes were very shallow, communal water sources, lacked a well protection construction and were located down slope. The water levels in these wells did not recede like in the other wells ever during the dry season. Rain water flowed into these wells collecting any debris and waste into the wells. A widely held precept in groundwater hydrology is that water flows downslope along the gradient of the groundwater surface or water table and this gradient generally conforms to the surface contours (Rutkoviene, *et al.*, 2005). Therefore, this affects well water because pollutants are carried down slope by runoff or general water flow. This tenet explains the high sanitary risk of wells found within the large and small farm sizes whereby the land slopes towards the well vicinity unlike in the medium farm sizes of Kaptagat ward where the farm lands are generally flat. Runoff down slope may introduce pollutants such as nitrates from fertilizers applied in the farms, animal excreta, organic waste, inorganic wastes.

These wells in the small farm sizes have a very high sanitary risk because they are found downslope and are not protected by raised construction. Livestock are often tethered and watered within the well vicinity; hence any animal wastes are washed into the wells from runoff down slope. Water quality in wells is highly influenced by pollutants moving from upslope in the vicinity of the well The deeper wells of the large farm sizes tended to have relatively lower than expected nitrate concentration which may be attributed to the below surface groundwater flow. It was observed that the water level in these wells frequently fluctuated with rainfall amount received unlike in the shallow wells whose water level remained noticeably visible.

VI. CONCLUSION

From this study it was apparent that there are multiple pollution point sources and risk factors that may determine the potential for environmental degradation on well water quality. The source of groundwater pollution comes from a variety of factors including the fertilizer application rates, well protection, well depth, groundwater level fluctuations and recharge conditions of the groundwater. The most important risk factors to the wells are the well protection and the activities within the well vicinity.

Farm characteristics can influence the SRF associated with individual wells and consequently the CRS. Efforts can be made to maintain the sanitary standards of the well as evidenced in the large and medium size farms. People may not be able to control the use of communal wells. Well sanitary risk was not of importance in choice of well location. There seemed to be lack of knowledge on the risks associated with well location. The raised construction on the wells reduced the likelihood of contamination from pollutants in the well vicinity. Well covers may not protect wells from rain runoff though they reduce the entry of surface flow of water. A widely held precept in groundwater hydrology is that water flows downslope along the gradient of the groundwater surface or water table and this gradient generally conforms to the surface contours. The small farm sizes had a very high sanitary risk because they were downslope and are not protected by raised construction.

There is therefore need for a local county initiative to construct protective raised walls at the communal wells and educate the community on aspects of water quality. It will be necessary to evaluate the microbial load and thereby determine the level of contamination associated with each well. Examination of the microbial levels alongside the sanitary risk scores will make it possible for local remedial actions. In addition it will be important in realising the national policy on Kenya's groundwater resources of providing a common framework to protect its quality by minimising the risks posed by pollution (Republic of Kenya (ROK). 2013).

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