ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES OF SHALLOW WELL WATER IN KAWANGWARE LOCATION, NAIROBI CITY COUNTY, KENYA

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ABSTRACT

Limited of access to portable water is adversely affecting the public health in many developing countries worldwide. Kawangware Ward in Dagoretti North Constituency is one of the areas undergoing rapid expansion in population, economic growth and urbanization in Nairobi County. This has significantly increased the pressure on public water supply systems in the county. The aim of this study was to determine the quality of water from shallow wells, which issued by households in Kawangware Ward for domestic purposes. In the months of July and August 2017, a total sample of 112 samples of water were collected in the morning and evening. The results of samples from Gatina site show that the following parameters were above the KEBs drinking water standards: turbidity ($\bar{x}$ =32.8; p=0.000), conductivity as EC ($\bar{x}$ =601.3; p=0.000), total dissolved solids ($\bar{x}$ =401.1; p=0.000), hardness as $CaCo_3$ ($\bar{x}$ =107.6; p=0.000), Sulphate as SO_4 ($\bar{x}$ =0.375; p=0.000), Nitrate as NO_3 ($\bar{x}$ =18.5; p=0.000), Phosphate as PO_4 ($\bar{x}$ =6.7; p=0.001), Lead as Pb ($\bar{x}$ =0.19; p=0.000), Cadmium as Cd ($\bar{x}$ = 0.04; p=0.000), Zinc as Zn ($\bar{x}$ =0.20; p=0.000), Sodium as Na ($\bar{x}$ =97.0; p=0.000) and Potassium as K ($\bar{x}$ =25.5; p=0.000). In the Kawangware site, the following parameters were found to be above the KEBs drinking water standards: pH ($\bar{x}$ = 7.8; p=0.000), Conductivity(EC) ($\bar{x}$ =966.3; p=0.000), Total dissolved solids ($\bar{x}$ =603.1; p=0.000), Hardness as $CaCo_3$ ($\bar{x}$ =164.8; p=0.000), Sulphate (SO_4) ($\bar{x}$ =0.44; p=0.000), Nitrate (NO_3) ($\bar{x}$ =18.4; p=0.000), Lead as Pb ($\bar{x}$ =0.08; p=0.000), Iron as Fe ($\bar{x}$ =0.18; p=0.001), Cadmium (Cd) ($\bar{x}$ =0.04; p=0.000), Zinc (Zn) ($\bar{x}$ =0.02; p=0.000) and Sodium (Na) ($\bar{x}$ =113.3; p=0.000). The Kabiro show that the following parameters were above the KEBs drinking water standards: pH ($\bar{x}$ = 8.1; p=0.002), Conductivity as EC ($\bar{x}$ = 310.7; p=0.001), TDS ($\bar{x}$ = 195.6; p=0.001), Hardness as $CaCo_3$ ($\bar{x}$ =13.8; p=0.001), Sulphate as SO_4 ($\bar{x}$ = 0.1; p=0.001), Nitrate as No_3 ($\bar{x}$ =17.9; p=0.001), Lead (Pb) ($\bar{x}$ =0.20; p=0.001), Iron as Fe ($\bar{x}$ =0.01; p=0.001), Cadmium (Cd) ($\bar{x}$ =0.04; p=0.001), Zinc (Zn) ($\bar{x}$ =0.01; p=0.001), Sodium (Na) ($\bar{x}$ =73.3; p=0.001) and Potassium as K ($\bar{x}$ =7.9; p=0.001). Therefore, the ground water from shallow wells in Kawangware is not safe for drinking due to elevated levels of nitrates, phosphates, turbidity, lead and cadmium levels which poses a great health risk to the public.

Key terms: *shallow well, ground water, water quality, water quality standards*

1.0 INTRODUCTION

The importance of water for the survival of plants and animals cannot be underrated. It is notable that water is at the core of sustainable development and plays a crucial role as far as energy and food production, socio-economic development, healthy ecosystems and human health is concerned. However, access to clean water remains a major challenge, thus forcing many people to device ways in which they can be able to acquire this noble commodity (Alves, Latorre, McCleod, Payen, Roaf, Rouse, 2016; WHO, 2019). As at 2019, 2.2 billion people lacked access to safely managed drinking water services while over 4.2 billion people failed to have a managed sanitation services (WHO, 2019).

In Kenya, the issue of ensuring sustainable provision of water and sanitation remains a pipe dream to many across the country, and this is despite it being one of the vision 2030 goals (Tibatemwa, 2017). It is notable that the water scarcity in Kenya is exuberated by increase in population growth in the recent past coupled by many years of recurrent droughts, climate change, poor management and conservation practices of the available water resources to prevent contamination (Tibatemwa, 2017). With most of the Kenyans only having access to polluted water, the issue of waterborne diseases is far from being eliminated. Such diseases like diarrhoea, cholera epidemics and multiple other diseases affect health and livelihoods. By 2018, it is notable that about 80% of people who attended hospitals in Kenya were diagnosed with preventable diseases, while 50% of these illnesses are water, sanitation and hygiene related (UNICEF, 2020). In Kawangware, one of the major towns in Nairobi, the issue of water scarcity and sanitation remains a major problem. The scarcity has resulted to increased number of waterborne diseases, malaria, respiratory pneumonia among other disease associated with poor sewerage system. It is due to the water shortage that dwellers in this area have depended on shallow wells to cater for their daily water needs, thus further exposing them to possible water contamination (Kinyanjui, 2014). Based on this, study aimed at critically evaluating the physico-chemical characteristics of groundwater quality in Kawangware location, Nairobi. Although several studies have been carried on the area regarding the quality of groundwater in the area, few studies have focused on water accessed from shallow wells thus this study aims to fill this gap.

2. 0 MATERIALS AND METHODS

2.1 Study area

The study was undertaken in Kawangware location of Nairobi County in Kenya. Kawangware lies between 1°16'60" S and 36°43'60" E. It is located approximately 15 km from Nairobi Central Business District (NCBD). It is adjacent to the rich agricultural county of Kiambu. It is sandwiched between Lavington and Kangemi. As per 2013, the population of the three study areas Kawangware, Gatina and Kabiro sublocation was 33,707, 43,627 and 33,707 respectively, and covers an area of 1.2, 1.5 and 1.2 square kilometers respectively.

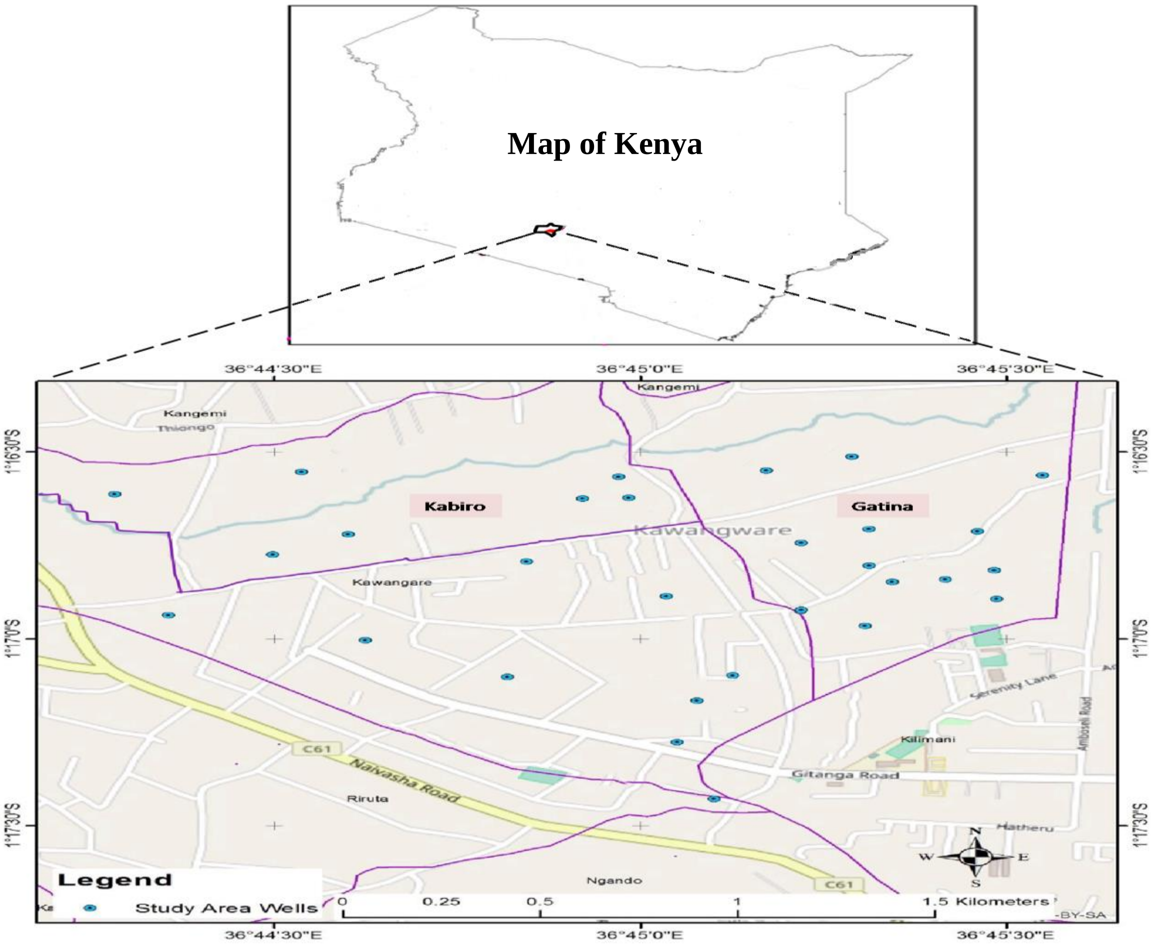

Figure 1: Map of Kawangware location showing sampling sites

2.2 Design of the study

Cross-sectional Survey research design was employed in the study to assess the level of physico-chemical of well water in the study area. Sample units were purposively selected.The study area is not homogeneous hence was clustered in three sub-location namely Kabiro, Gatina and Kawangware.

The sample size was determined using Yamane's simplified method of determining sample size i.e. $n=N/\{1+N(e)^2\}$ (Polonia, 2013)

Where:

n = Sample Size

e = Error Limit (0.1)

N= Population Size

The wells were sampled as follows amongst three sub-locations namely Kabiro, Gatina and Kawangware 7, 13, 8 wells respectively giving a total of 28 wells. All the wells were purposively selected. Samples were collected in the month of July 2017 and the same was repeated in the month of August 2017. The Samples were collected twice a day, in the morning hours between 6.00 am-9.00am and evening 3.00pm-5.00pm when the residents were fetching water. A total sample of 112 was collected.

2.3 Sampling procedure of the study

A volume of one liter water samples for physico-chemical analysis from the shallow wells were collected in clean plastic bottles .In-situ measurements of temperature, pH, Electrical conductivity (EC) and TDS were carried out in the field at the point of sampling. Samples for analysis of Zn,Pb,Fe and Cd were preserved with 2 ml concentrated nitric acid. There after the samples were packed in cool boxes and transported to the laboratory for further analysis. Turbid samples for laboratory analysis were filtered using a 0.45 μm pore diameter filter papers before analysis. All samples were stored refrigeration conditions at 4^0 C. Water samples for microbiological analysis were collected in glass bottles. The bottles had been washed and sterilized at 121° C prior to sampling. The water sample bottles were labeled with the name of the site, date and time of sampling. They were carried in a cool box and transported to the laboratory under refrigeration condition within 6 hours for analysis. Samples not analyzed on the same day were stored in the refrigerator at 4^0 C for not more than 24 hours.

2.4 Physico-chemical Analysis

The parameters tested were temperature, PH, electrical conductivity, total dissolved solids, turbidity, total hardness, sodium, potassium, nitrates, phosphate, sulphates, Zn, Pb, Fe and Cd.

The parameters were tested in accordance with the Standard methods for the Examination of water and waste waters (APHA, 2005) and the results obtained were compared with KEBS drinking water guideline in order to determine the quality of water and hence the suitability of the groundwater used in Kawangware. Selected parameters were analyzed for each sample collected. All the equipments were calibrated and distilled water used throughout the analysis. In-situ measurements were done for temperature, electrical conductivity, total dissolved solids, pH and turbidity were taken in accordance to (APHA, 2005).

2.5 Data Analysis

The data obtained from the analyzed physico-chemical and microbiological parameters was displayed on tables and graphically using excel and compared KEBS (local standards) to check if they fall within acceptable limits. The collected data was captured in STATA-14 software which generated means and standard deviation to help in answering research objectives. The formulated hypotheses were tested using the students' t- test at 95% confidence interval.

3.0 RESULTS AND DISCUSSION

Physico-chemical parameters of groundwater used by household in Kawangware

The minimum, maximum and mean values of the physico-chemical properties of groundwater in Kawangware location are shown in Table 3.1 to table 3.3 respectively.

Table 3.1: Physico-chemical parameters of groundwater for Kabiro site

Parameters	units	Mean	KEBS (2010)	Std. Dev	Range		p-value
					Min.	Max.	
Temperature	°C	23.5	-	2.02	20.9	26.4	-
pH		8.1	6.5-8.5	0.24	7.8	8.69	0.002
Conductivity as EC	µS/cm	310.7	2500	24.46	270.5	350.0	0.001
TDS	mg/l	195.6	1500	15.91	167.7	217.0	0.001
Turbidity	NTU	16.0	5	35.77	0.0	100.9	0.149
Hardness as $CaCo_3$	mg/l	13.8	500	5.49	9.41	27.0	0.001
Sulphate as SO_4	mg/l	0.1	450	0.26	0.01	1.0	0.001
Nitrate as No_3	mg/l	17.9	10	1.66	14.3	20.1	0.001
Phosphate as PO_4	mg/l	6.1	2.2	5.91	0.04	14.0	0.084
Lead asPb	mg/l	0.2	0.01	0.34	0.06	1.0	0.001
Iron as Fe	mg/l	0.1	0.3	0.04	0.03	0.17	0.001
Cadmium as Cd	mg/l	0.04	0.003	0.007	0.03	0.06	0.001
Zinc as Zn	mg/l	0.1	5	0.10	0.001	0.3	0.001
Sodium as Na	mg/l	73.3	200	3.77	65.8	80.0	0.001
Potassium as K	mg/l	7.9	50	1.08	6.0	10.0	0.001

In Kabiro site, all other parameters were within the acceptable limits for drinking water according to KEBS standards except for turbidity, nitrates and phosphates which were much beyond the KEBS standards. Cadmium was also evident in the water from this site as seen in table 3.

Table 3.2: Physico-chemical parameters of ground for Kawangware site

Parameters	Units	Mean	KEBS (2010)	Std. Dev.	Range		p-Value
					Min.	Max.	
Temperature	°C	22.0	-	2.72	19.5	28.8	
Ph		7.8	6.5-8.5	0.33	7.21	8.34	0.000
Conductivity(EC)	µS/cm	966.3	2500	540.18	118.2	1593.1	0.000
Total dissolved solids	mg/l	603.1	1500	336.47	73.82	987.7	0.000
Turbidity	NTU	12.0	5	14.84	0.0	50.1	0.066
Hardness as $CaCo_3$	mg/l	164.8	500	106.94	8.9	345.26	0.000
Sulphate (SO_4)	mg/l	0.44	450	0.52	0.03	1.12	0.000
Nitrate (NO_3)	mg/l	18.4	10	0.51	17.5	19.7	0.000
Phosphate(PO_4)	mg/l	9.5	2.2	13.87	0.02	42.8	0.234
Lead as Pb	mg/l	0.08	0.01	0.01	0.06	0.09	0.000
Iron as Fe	mg/l	0.18	0.3	0.07	0.01	0.3	0.001
Cadmium(Cd)	mg/l	0.04	0.003	0.01	0.03	0.05	0.000
Zinc (Zn)	mg/l	0.02	5	0.01	0.01	0.03	0.000
Sodium (Na)	mg/l	113.3	200	26.24	74.5	154	0.000
Potassium (K)	mg/l	39.8	50	32.02	6.0	116	0.134

Water from Kawangware site was characterised by high levels of turbidity, nitrates and phosphates in addition to exhibiting substantial levels of heavy metals like lead and cadmium beyond the maximum limits as desired by KEBS as seen in table 3.2.

Table 3.3: Physico-chemical parameters of ground for Gatina site

Parameters	Units	Mean	KEBS (2010)	Std. Dev.	Range		p-value
					Min.	Max.	
Temperature	°C	21.76	-	3.08	17.5	30.1	
PH		8.4	6.5-8.5	0.85	7.2	9.88	0.7501
Conductivity as EC	µS/cm	601.3	2500	322.3	117	1254.6	0.000
Total dissolved solids	mg/l	401.1	1500	200.79	121.7	777.9	0.000
Turbidity	NTU	32.8	5	25.33	0.6	78	0.000
Hardness as $CaCo_3$	mg/l	107.6	500	0.13	11.9	234	0.000
Sulphate as SO_4	mg/l	0.375	450	0.44	0.01	1.5	0.000
Nitrate as NO_3	mg/l	18.5	10	0.68	17	19.8	0.000
Phosphate as PO_4	mg/l	6.7	2.2	5.28	0.02	15.8	0.001
Lead asPb	mg/l	0.19	0.01	0.30	0.05	1	0.000
Iron as Fe	mg/l	0.3	0.3	0.30	0.07	1	0.058
Cadmium as Cd	mg/l	0.04	0.003	0.01	0.03	0.06	0.000
Zinc as Zn	mg/l	0.2	5.0	0.34	0.01	1.2	0.000
Sodium as Na	mg/l	97.0	200	23.51	68.7	142.2	0.000
Potassium as K	mg/l	25.5	50	17.47	7.5	55	0.000

In Gatina site, all other parameters were within the acceptable limits for drinking water according to KEBS standards except for turbidity, nitrates and phosphates which were much beyond the permissible levels according to KEBS standards. Cadmium and lead were also evident in the water from this site as seen in table 3.3.

3.2.1 Temperature

The mean temperature for the water samples in the study area ranged from 21.76º C to 23.5º C with Kabiro recording the highest temperature of 23.5º C and the lowest temperature of 21.76º C recorded at Gatina as seen in figure 3.1.

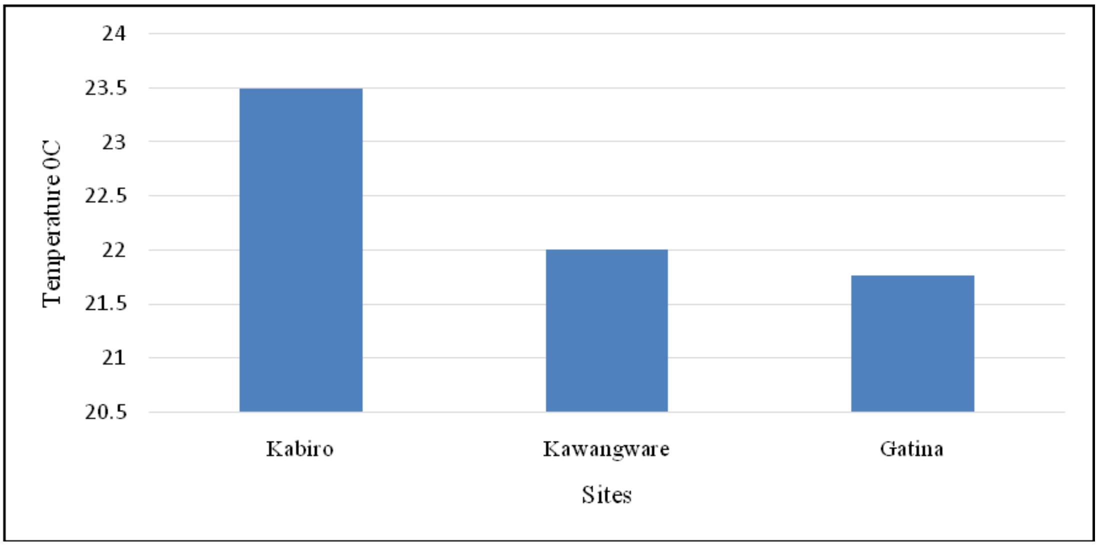

Figure 3.1: Mean temperatures of the shallow well water in Kawangware location

It is notable that the relatively low temperatures are due to the general cool weather that prevailed during the sampling times; in the morning and evening. Water temperature plays an important role by influencing the chemical and bio-chemical characteristics of water. High temperature decreases the solubility of different gases especially carbon dioxide and other volatile gases which impart taste in the water (Karunakaran, et al., 2009). However, temperature of a water body is affected by a number of factors such as climate and the effect of direct sunlight and depth of the water (Ekhaise and Anyansi, 2005).

3.2.2 pH

The mean pH for the entire study area ranged from 7.8 to 8.4 with the highest of 8.4 being recorded at Gatina and the lowest value of 7.8 at Kawangware with Kabiro recoding a pH value of 8.1 (Figure 3.2). The pH for all the samples in the area were slightly basic hence making the water toxic (Safdar et.al, 2013). There was a significant difference ($p \leq 0.05$) between pH of Kabiro and Kawangware sites and those of KEBS (Table 3.1 and 3.2). While there was no significance difference ($p \leq 0.7501$) between the pH of Gatina and KEBS (Table 3.3) however, the pH of the water in the area was within the acceptable standards in accordance to KEBS as per the figure 3.2.

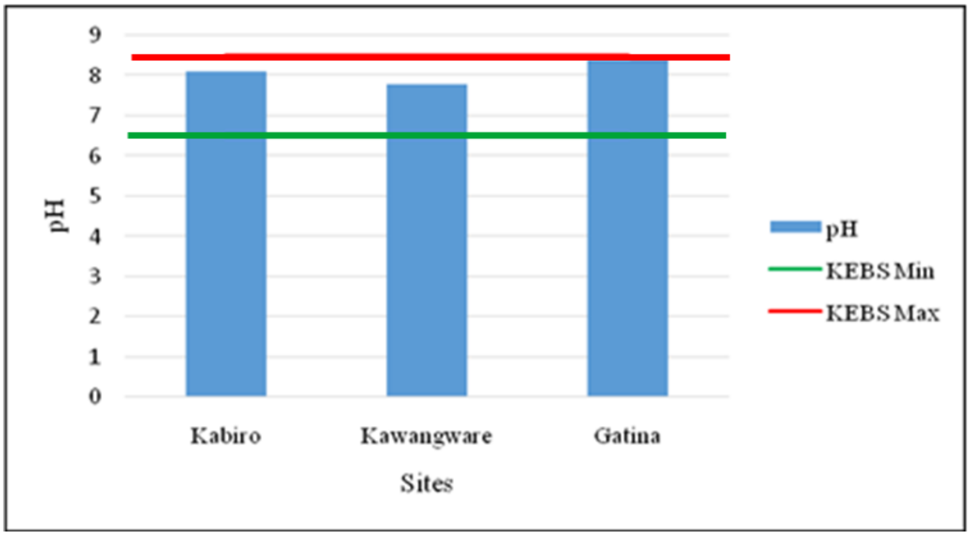

Figure 3.2: Mean pH levels of the shallow well water in Kawangware location

Temperatures bring about changes in the pH of water by bringing about changes in the physico-chemical condition of the water (Trivedi, et al., 2009). The cool temperature water did not favour the chemical activities in water which could have resulted to either decrease or increase in pH. Similar trends were experienced by (Basavaraja et al., 2011) in their study on the quality of water in India.

3.2.3 Electrical conductivity

Mean conductivity of water samples ranged between 310.7 µS/cm and 966.3 µS/cm with the lowest being recorded at Kabiro and highest at Kawangware (Table 3.2 and 3.3).Gatina sub-location recorded a value of 601.3µS/cm, although these values fell within the KEBS acceptable limits of 2500µS/cm as per figure 3.3)

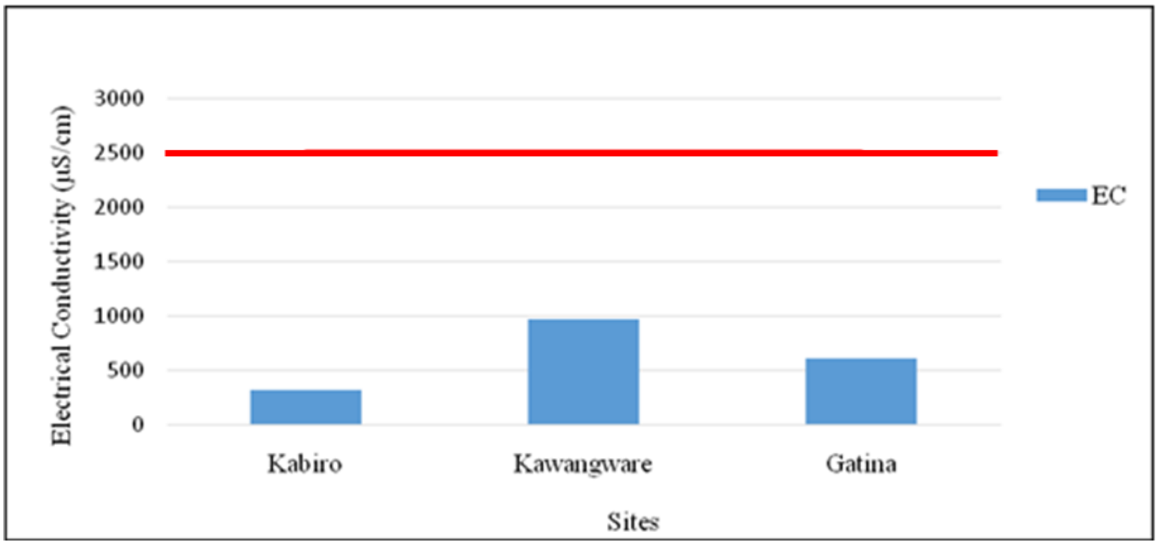

Figure 3.3: Mean Electrical conductivity of the shallow well water in Kawangware location

From the figure 3.3, it is important to note that, there was a significant difference ($p \leq 0.05$) between the mean conductivity values for all the sites and that of KEBS (Table 3.1, 3.2 and 3.3). The Electrical conductivity of the water in this area was much lower as compared to that of KEBS. Similar trends in electrical conductivity have been observed in studies by (Adejuwon & Mbuk , 2011) on the biological and physiochemical properties of shallow wells in Ikorodu town of Nigeria. This means that the water in the study is a poor conductor of electric current as it is not ionized (Basavaraja et al., 2011).

3.2.4 Turbidity

Turbidity of the well water samples varied from 12.0 to 32.8 NTU with the lowest recorded at Kawangware and the highest at Gatina (Table 3.1, 3.2 and 3.3) Kabiro sites recorded a mean turbidity value of 16.0 NTU. These values exceeded the KEBS recommended limits 5.0 NTU rendering the water unsuitable for domestic use as demonstrated in figure 3.4

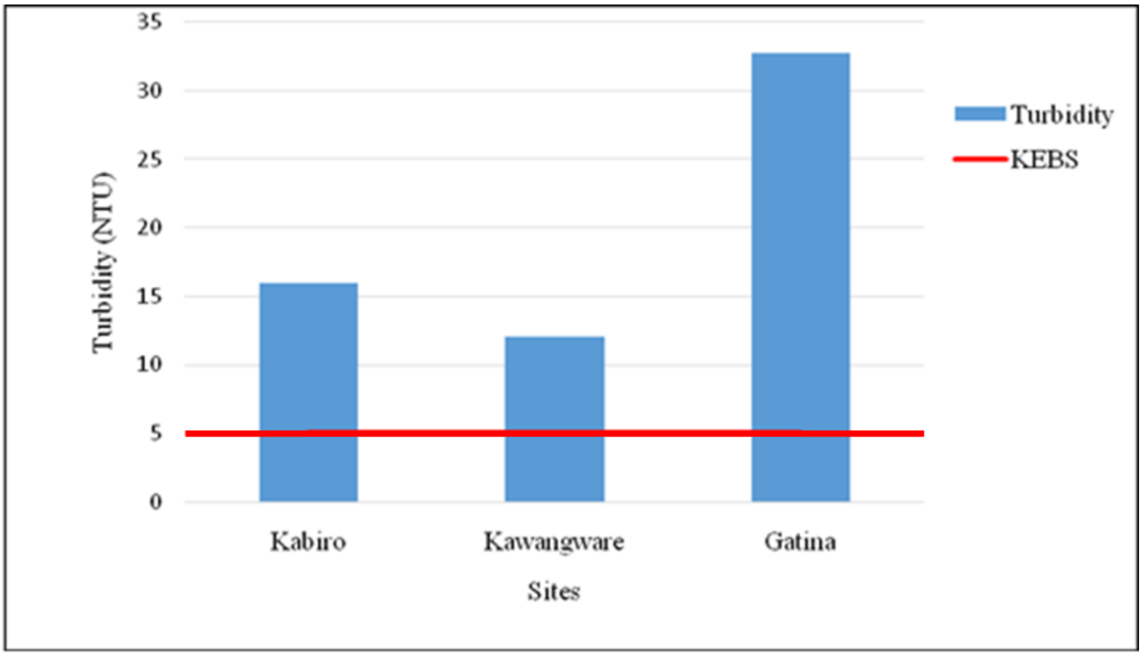

Figure 3.4: Mean turbidity levels of the shallow well water in Kawangware location

However, there was no significant differences ($p \leq 0.05$) between the mean turbidity values for the samples from Kabiro and Kawangware sites with that of KEBS but the difference was so significant ($p \leq 0.05$) between the mean concentrations of water samples from Gatina site and those of KEBS. Gatina recorded a mean level of 32.8 NTU. The elevated turbidity in this waters may be due to human activities, decrease in the water level and presence of suspended particulate matter due to the nature of the wells which tend to allow in drain water as they are not completely covered (Khopkar, 2006). Water of high turbidity is aesthetically unacceptable. Turbid waters are also associated with the presence of disease causing microorganisms.

3.2.5 Total Dissolved Solids

Mean total dissolved solids concentrations ranged from 195.6 to 603.1 mg/l with the highest values recorded at Kawangware (Table 3.2) and the lowest at Kabiro (Table 3.1). Gatina recorded a TDS of 401.1 mg/l (Table 3.3).The total dissolved solids were within the KEBS acceptable limits of 1500 mg/(figure 3.5)

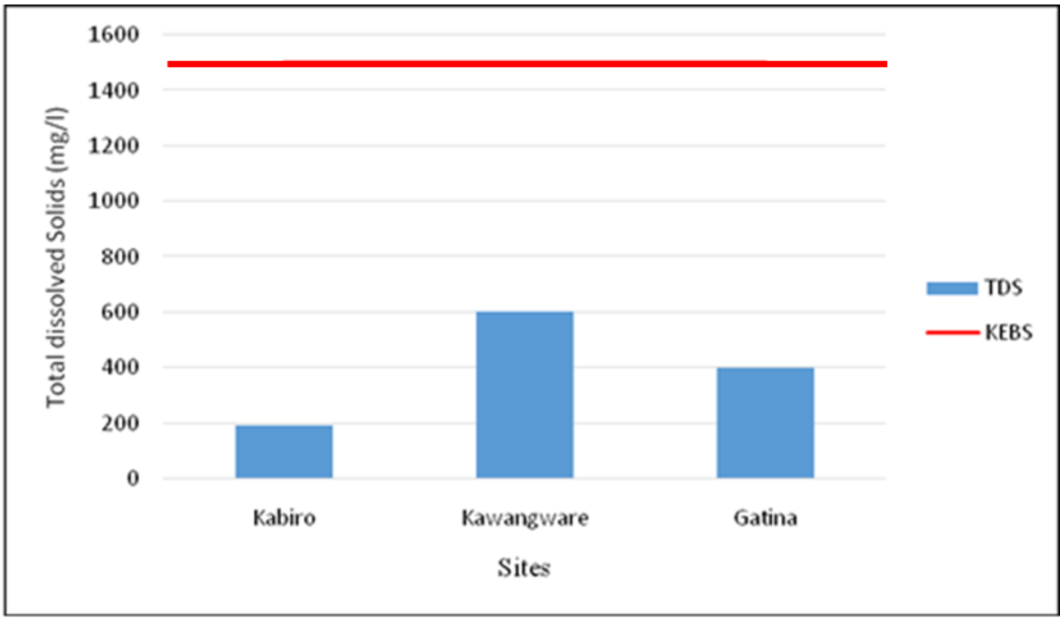

Figure 3.5: Mean total dissolved solids of the shallow well water in Kawangware location

From figure 3.5, it is clear that here was significant difference ($p \leq 0.05$) between the mean concentration for the samples in all the sites and that of KEBS. There total dissolved solids (TDS) in this area were much lower as compared to those of KEBS. TDS indicates the amount of inorganic substances in water and thus a good indicator of pollution. Elevated levels of TDS in drinking water have been associated with natural sources like sewage runoff and industrial effluent discharges in water sources (Olajire & Imeokparia, 2001).

3.2.6 Total Hardness

The average hardness for the water samples ranged from 13.8 to 164.84 mg/l with the lowest concentration recorded at Kabiro while the highest at Kawangware site (Table 4.1 and 4.2). Gatina had 106.63 mg/l (Table 3.3). There was a significant difference ($p \leq 0.05$) between the mean concentration of all sites and those of KEBS. The total hardness values were much lower and within the KEBS permissible limit of 500 ml/l as per figure 3.6.

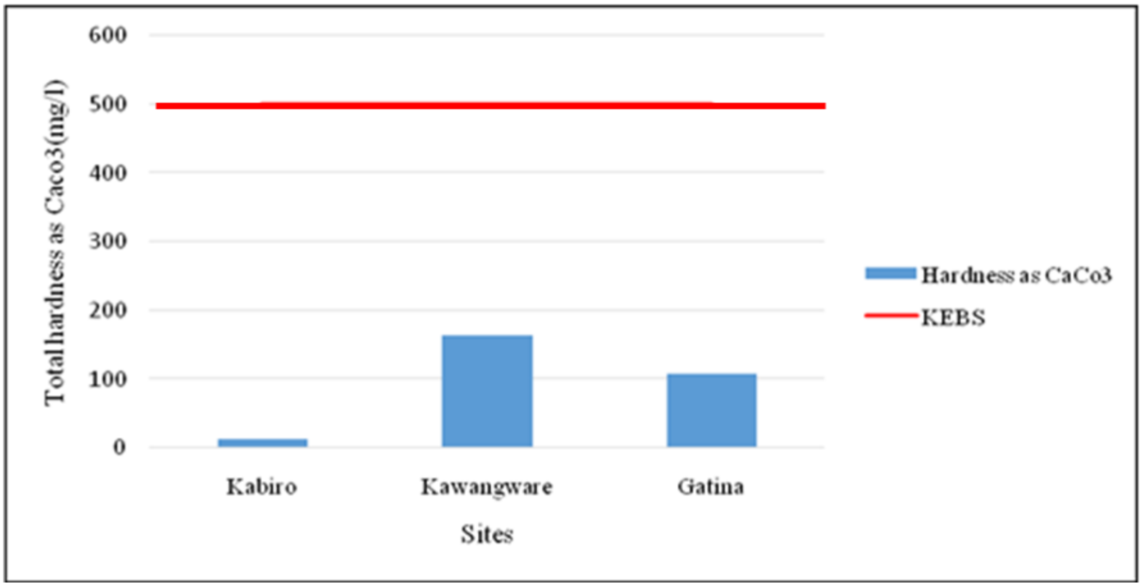

Figure 3.6: Mean total hardness of the shallow well water in Kawangware location

Total hardness is often measured as a combination calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$). According to (McGowan, 2000), the water in Kawangware location was found to be hard since water containing calcium carbonate ($CaCO_3$) at concentrations below 60 mg/l is generally considered as soft. Hard water contains 120–180 mg/l ($CaCO_3$) while more than 180 mg/l ($CaCO_3$) is considered as very hard water. Similar trends of shallow well water having low hardness were noticed by (Ashun, 2014) in his study of on water quality of groundwater in Thiririka sub location of Kiambu County.

3.2.7 Sulphate

The mean Sulphate levels ranged from 0.10 to 0.44 mg/l. The highest value of 0.44 mg/l was recorded at Kawangware while Kabiro recorded the lowest value of 0.10 mg/l. Gatina recorded sulphate concentration of 0.3 mg/l (Table 3.1, 3.2 and 3.3). KEBS recommends maximum allowable sulphate levels of 450 mg/l in water used for drinking purposes and therefore the levels for water samples of all sites were within the acceptable levels of KEBS. There was a significant difference ($p \leq 0.05$) between the mean concentration of all sites and those of KEBS. The mean sulphate concentrations of the water in this area are much lower as compared to that of KEBS.

3.2.8 Nitrate

The mean concentration of nitrates in the shallow well waters ranged between 17.9 mg/l and 18.5 mg/ml. They highest level was recorded at Gatina sub- location while the lowest at Kabiro sub- location with Kawangware recording a level of 18.4 mg/l. There was a significant different ($p \leq 0.05$) between the mean concentration of nitrates in this area and those of KEBS. The mean nitrate levels of the sampled water were above the 10.0 mg/L guideline value prescribed by KEBS as seen in figure 3.7.

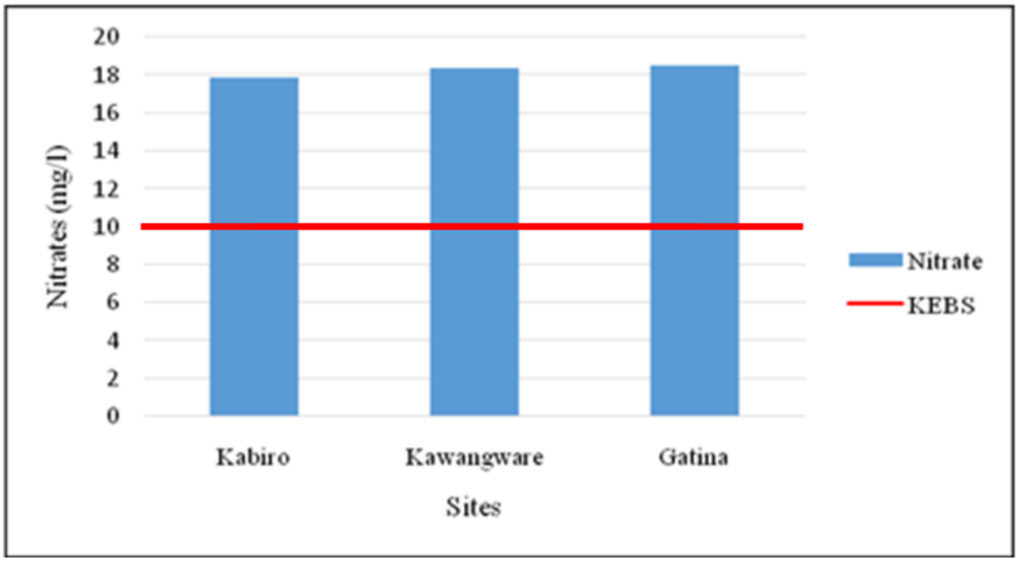

Figure 3.7: Mean Nitrate of the shallow well water in Kawangware location

The high levels (as seen in the figure 3.7) is an indication of contaminated water hence rendering it not suitable for human consumption. Elevated nitrate levels in the water may cause methemoglobinemia also referred to as 'blue baby syndrome' in infants and a cancer of the stomach in adults (WHO, 2011) The high concentration of nitrates in the shallow wells water may be due pollution by human and animal sewage through surface runoff into these wells. The use of pit latrines, poor solid waste management is the major sources of nitrates in these wells. High nitrate levels also stimulate algal growth play a role in eutrophication (Steffii et al., 2003).

3.2.9 Phosphate

Mean phosphate concentration of the sampled water ranged between 6.10 and 9.50 mg/l The highest value was recorded at Kawangware and the lowest at Kabiro (Table 3.1 and 3.2) while Gatina recorded 6.70 mg/l (Table 3.3).There was significant differences ($p \leq 0.05$) in the mean of phosphate between the water samples for Gatina and KEBs.Kabiro and Kawangware the difference was not significant, while rom all the sites with that of KEBS. Phosphate concentrations in the samples exceeded the KEBS permissible limit of 2.2 mg/l as seen in figure 3.8.

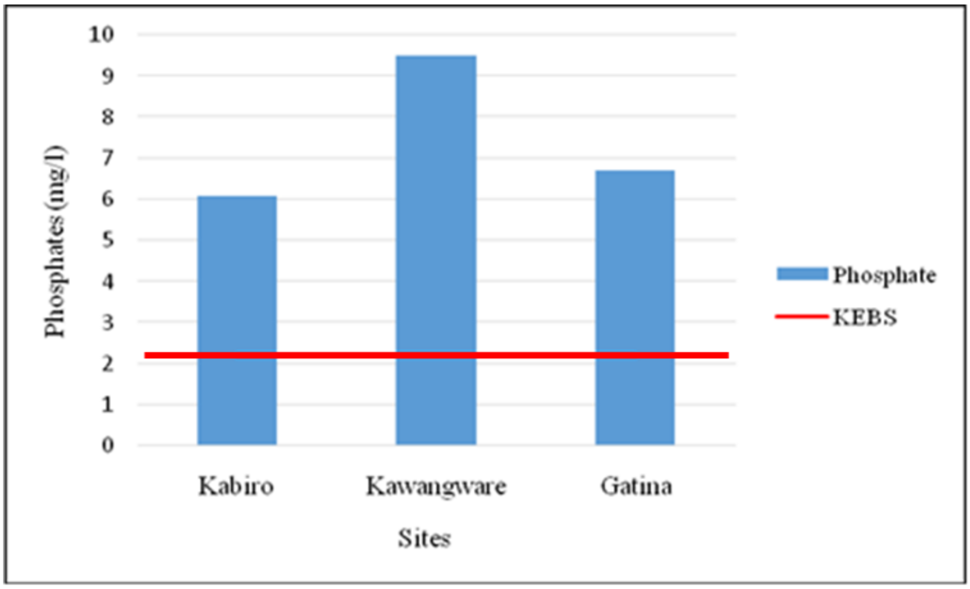

Figure 3.8: Mean phosphate levels of the shallow well water in Kawangware location

The extremely high levels of phosphates can cause digestive problems in humans while in water it promotes the growth of algae and weeds which use up large amounts of oxygen. These algae produce and harbor toxins which contaminate the water (WHO, 2006; WRC, 2002). High levels of this compound in the water could be due to the indiscriminate use of such detergents (Sheila, 2005).The use of pit latrines and on-site septic systems could be another cause of the high levels of phosphorous in the water since such systems leak through the soils to the waters (WHO, 2006).

3.2.10 Iron

The mean level of Iron in the water samples for Kawangware location ranged from 0.1 to 0.3 mg/l (Table 3.1 to 3.3). The highest value of 0.3 mg/l was recorded at Gatina site while Kabiro recorded the lowest value of 0.10 mg/l with Kawangware sub-location recording 0.18 mg/l. There was a significant differences ($p \leq 0.05$) between the Iron concentrations of water samples from Kabiro and Kawangware sites but the difference was not significant ($p \leq 0.05$) between the samples from Gatina site with that of KEBS as compared in the figure 3.9.

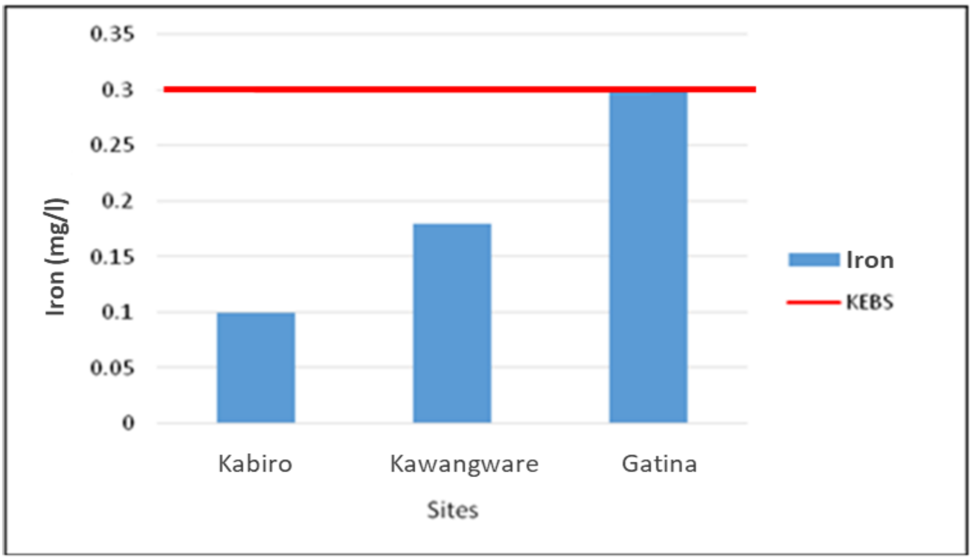

Figure 3.9: Mean Iron levels the shallow well water in Kawangware location

However, it is notable that iron concentration in the water did not exceed the acceptable levels of 0.3 mg/l according to KEBS guidelines. The Iron concentrations from the water from Kabiro and Kawangware sub-locations were very much lower as compared to that of water from Gatina which was slightly higher. Iron has no health effect on healthy individual as it is one of the essential trace metal required by the body. However, it could impart taste and offensive odour in water at concentration greater than 0.3 mg/l (WHO, 2006).

3.2.11 Lead

Concentration of lead in the water ranged between 0.08 mg/l and 0.20 mg/l (Table 3.1 and 3.3). Lead levels were highest at Kabiro site and the lowest recorded at Kawangware site. Gatina sub-location recorded a lead concentration of 0.19 mg/l. The difference in lead concentrations between the sites and KEBS standards was significant ($p \leq 0.05$). The lead levels elevated throughout the study area and therefore above the acceptable limit of 0.01 mg/l prescribed by KEBS as seen in figure 3.10

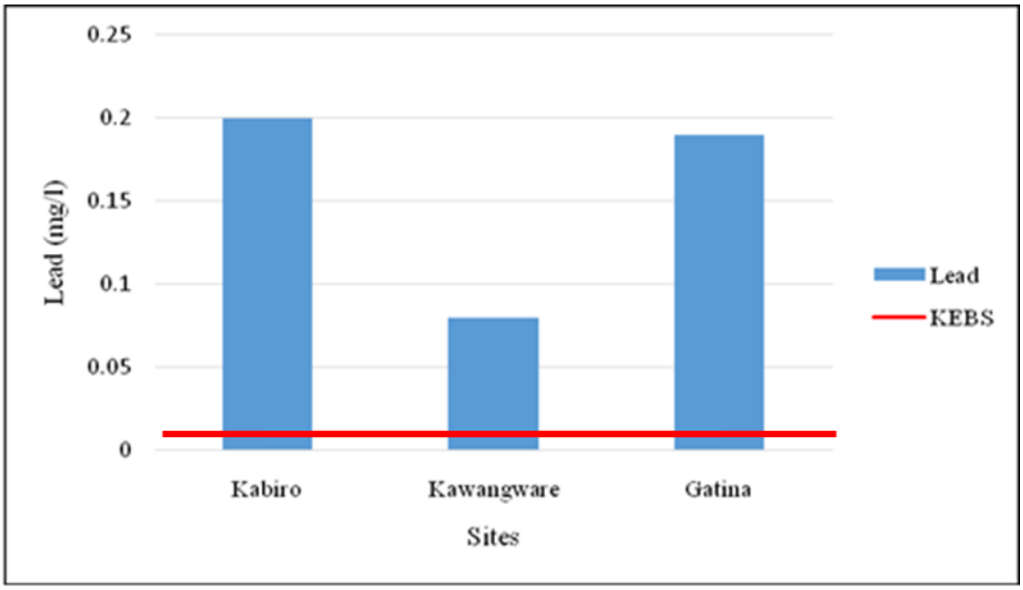

Figure 3.10: Mean lead levels of the shallow well water in Kawangware location

It is notable that the major source of lead pollution in the environment and water bodies is the use of leaded products such as paint, car batteries, petrol as well as industrial discharges. Improper disposal of used lead products could easily lead to water contamination through leaching to the groundwater via the soil (Tole & Jenipher, 2001). A high level of lead in blood (above 0.04 mg/l) is known to reduce fertility especially among men and raise the risks of spontaneous abortion, preterm delivery and various neurodevelopmental effects (WHO, 2004).

3.2.12 Cadmium

The mean level of cadmium in the water samples for all the sites was 0.04 mg/l (Table 3.1 to 3.3). There was a significant difference ($p \leq 0.05$) between the mean levels of cadmium in all the sites with that of KEBS. These concentrations were far above the acceptable limit of 0.003 mg/l prescribed by KEBS as per figure 3.11.

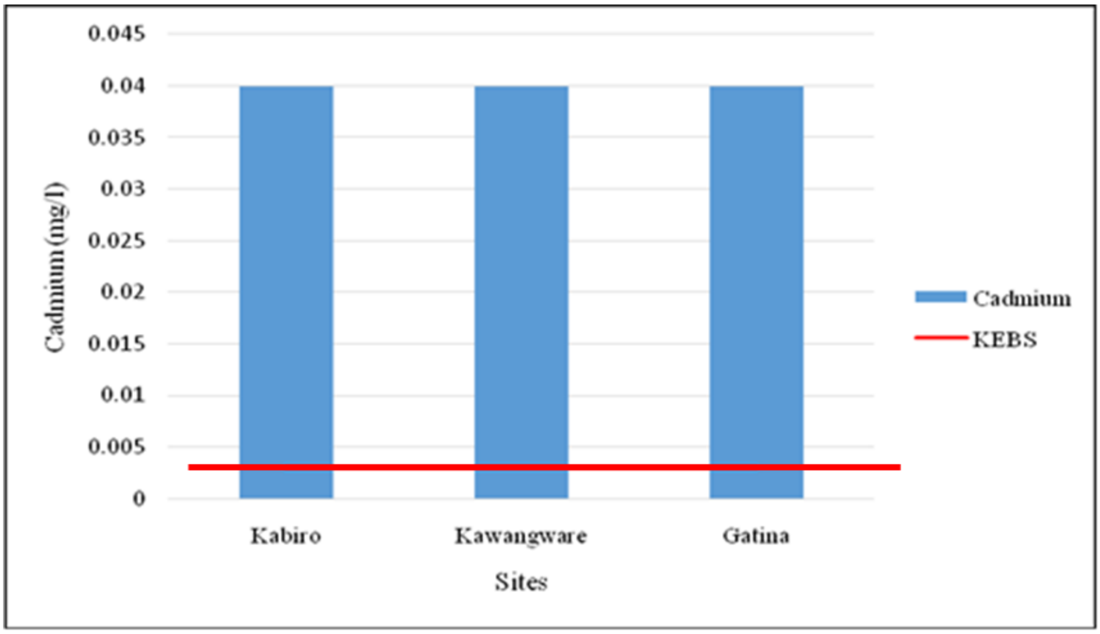

Figure 3.11: Mean cadmium levels of the shallow well water in Kawangware location

The presence of cadmium in well waters may be attributed to the geological factors rather than anthropogenic pollutants input (Olago & Akech, 2001). Long term exposure to cadmium leads to bioaccumulation in the body tissues. The effect of this leads to immediate poisoning and damage to the liver and the kidneys. Cadmium also causes anaemia and hepatic disorder (Sen & Khurana, 2009).According to Muraguri (2013), the presence of cadmium in groundwater in Nairobi may be explained by geological factors ratherthan anthropogenic pollutants input.

3.2.13 Zinc

The mean level of zinc in the water samples analysed for Kawangware location ranged from 0.02 to 0.2 mg/l (Table 3.1 to 3.3). The highest value of 0.20 mg/l was recorded at Gatina and Kawangware recorded the lowest value of 0.02 mg/l (Table 3.2) with Kabiro sub-location recording 0.1 mg/l (Table 3.1). There was a significant differences ($p \leq 0.05$) between the mean levels of zinc in water from all sites and that of KEBS. The mean zinc concentrations were much lower to that of KEBS. However, the values were within the acceptable limit of 5.00 mg/l prescribed by KEBS (Figure 3.13). These results are supported by Muraguri (2013) in his study of the groundwater in Nairobi County. The report indicated similar low concentrations in various areas within the county.

3.2.14 Sodium

The mean sodium levels in the study area ranged between 73.3 mg/l recorded at Kabiro (Table 3.1) to 113.3 mg/l recorded at Kawangware site (Table 3.2). Gatina site recorded a mean of 97 mg/l. The difference in the sodium levels in all sites were significant ($p \leq 0.05$) with those of the KEBS (Table 3.1 to 3.3). The sodium levels of the water were much lower as compared to those of KEBS as per figure 3.12.

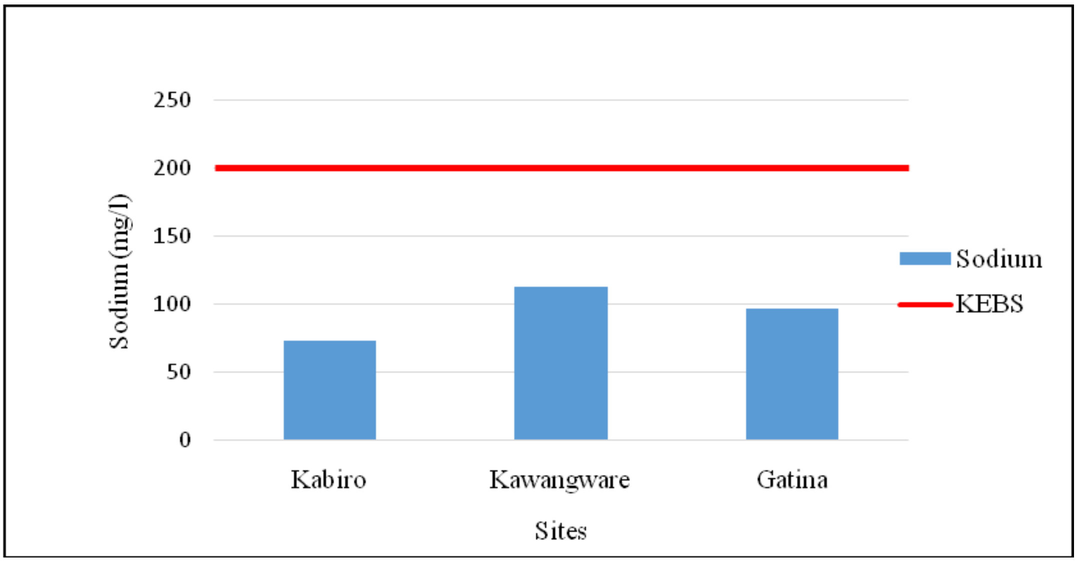

Figure 3.12: Mean Sodium levels of the shallow well water in Kawangware location

The results showed that the levels of sodium did not exceed the guideline value of 200 mg/l according to KEBS. Sodium ions are usually a factor of the rock and soils of the area and this will determine its concentrations in the water. Not only seas, but also lakes, rivers and groundwater contain significant amounts of sodium. Its concentrations however are mainly dependent on geological conditions and levels of wastewater contamination (WHO, 2003).

3.2.15 Potassium

Potassium ion is an essential element required to maintain ionic balances in human body. However, long term ingestion resulting to potassium ions overloads the homeostatic functions of the body and may lead to kidney problems (Marian & Ephraim, 2009). The mean potassium levels ranged between 7.9 mg/l for Kabiro sub-location and 39.8 mg/l recorded at Kawangware site, while Gatina site recorded 25.5 mg/l. The mean potassium levels of the water were within the acceptable levels of 50 mg/l according to KEBS standards as indicated in figure 3.13.

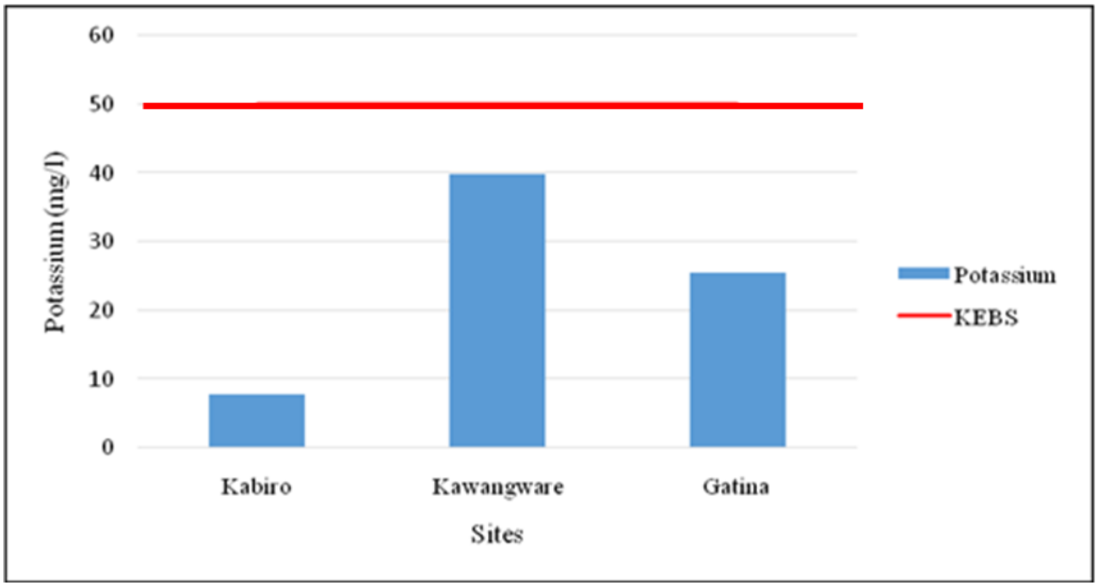

Figure 3.13: Mean potassium levels of the shallow well water in Kawangware location

However, the difference was significance ($p \leq 0.05$) between the mean potassium levels of Kabiro and Gatina and that of KEBS. The levels of potassium in these areas were much below the KEBS recommended levels but within the acceptable limits. For Kawangware site, the difference was not significant ($p \leq 0.134$) though within the acceptable levels. The slightly higher levels of potassium seen in Kawangware site may be attributed to leakage of domestic and animal sewage into the wells because of the nature and entire hygiene conditions surrounding these shallow wells. These findings are similar to the study by Safdar, et al. (2013) on drinking water quality and its impact on residents Health in Bahawalpur City. In this study the potassium level of the water were found to be very low.

4.0 CONCLUSION AND RECOMMENDATION

The results of the study indicated that the quality of the groundwater of the study area did not meet expectations in terms of nitrates, phosphates and was of high turbidity which would definitely affect the taste. These parameters had higher values greater than KEBS recommended standards for drinking water. The presence of considerable concentrations of cadmium and lead in groundwater samples is a major concern to public health. However, other parameters were within the permissible standards according to KEBS requirements for

TDS, conductivity, sulphates, potassium, total hardness, and zinc. From the study area, it is clear that the levels of the following physico-chemical parameters were higher than the recommended KEBS standards turbidly, nitrate, phosphates turbidity, lead and cadmium. In recommendation, there is the need to establish an efficient periodic monitoring system to evaluate levels of chemical properties especially for parameters like lead and cadmium in groundwater since they are a threat to health after bioaccumulation.

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