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The Assessment of The Effect of Proximity of Septic Tanks on The Levels of Selected Heavy Metals in Borehole Water from Ongata Rongai, Kajiado County, Kenya

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ABSTRACT

The study was carried out to evaluate the levels of heavy metals in groundwater samples from ten selected boreholes in Ongata Rongai town, Kajiado County. The selected heavy metals analyzed were: Zn, Pb, Hg, Mn, Cd and Cr in the dry and wet seasons. The effect of the proximity of septic tanks distance to borehole was also determined. The statistical analyses of the data using a 2-way ANOVA showed 95% confidence level ($p<0.05$) interdependence of the distance from the boreholes and contaminant levels. The study showed that heavy metals were below the maximum recommended level and the guideline values of World Health Organization and Kenya Bureau of Standards. The analyses of the selected heavy metals, by Flame Atomic Absorption Spectroscopy, revealed that the detected levels of Mn (0.03±0.01 - 0.26±0.01 mgl^{-1}) were higher than those recommended by WHO and KEBS of 0.01 mgl^{-1}, while Zn (0.11±0.02 - 0.73±0.01 mgl^{-1}) are within acceptable levels of WHO (3.0 mgl^{-1}) and KEBS (5.0 mgl^{-1}). There was no strong correlation between the distance of borehole from septic tanks and heavy metal levels in water samples. The low detected values should not be overlooked as the heavy metals are capable of bio-accumulating in body tissues.

Keywords: Heavy metals, Septic tank distance, borehole water, assessment, Levels

I. INTRODUCTION

The study by [1] described heavy metals as a metal element that has a comparably high density and are hazardous at little concentrations. However, [2] were more specific and described heavy metals as "Groups or metals or metalloids with an atomic density larger than 4 g/cm^3 or is 5 times denser than water". [2] Emphasized that the "Density of heavy metal is of minimal concern but the emphasis should be placed on their chemical properties instead" [3].

The health effects of heavy metals and metalloid contamination in the surrounding environment is a growing concern globally as reported by [4] they attributed this is due to the persistence of heavy metals. Mercury, Lead, Cadmium, and Arsenic have been known to cause detrimental health problems [5]. These metals naturally occur in the surrounding but are also released into the environment due to anthropogenic activities that largely contribute to their existence in the environment. [4] list some of the anthropogenic activities that lead to the release of heavy metals into the environment as mining, industrial waste disposal, transport sector, agricultural activities, and the domestic effluent disposal systems. The study carried out by [6] also added that both natural and anthropogenic process lead emission of heavy metals to the environment. The metal ions bio accumulate in biota and are removed by desorption into the environment, leading to their toxic nature among other abundant sources [7] and as such, there is need to assess the concentrations of heavy metal regularly in the environment. Heavy metals occur in our environment as particulates, dissolved and colloidal phases [8].

Therefore, it is important to assess the chemical characteristics of water and determine the concentrations of heavy metals. They are currently the most persistent water impurities with known detrimental effects on human health. These heavy metals are transported in water as an outcome of improper disposal of industrial waste, electronic waste, municipal wastewater, landfill leachates, mining activities and natural geochemical weathering of rocks [4]. They also added that volatile and particulate metal compounds are carried from one place to another by the wind. These heavy metals include; Lead, Zinc, Mercury, Manganese, Chromium, and Cadmium. However, according to [9], the concentration of these metals has greatly increased due to human activities.

Septic tanks as a source of groundwater contamination

Human excreta contains traces of heavy metals, in feces and in urine, which have a characteristic of accumulation in the soil, sediment, and would eventually reach the groundwater, from within 3 days to months and therefore the recommended distances of septic tanks from boreholes is 50 feet or approximately 15m according to [10] as shown in Figure 1. [11] acknowledge the risk posed by cesspits to underground water by highlighting that the largest risks of human exposure from contents discharged into a soak pit or cesspit occur during emptying the pit contents, or through contamination of groundwater when used as a source of drinking water in proximity of the effluent leaving a soak pit, and when a pit is overflowing due to system malfunctioning.

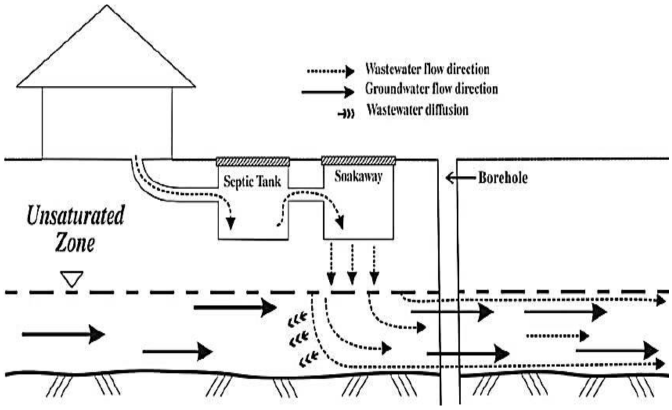

Figure 1 : Septic tank soakway system, waste water flowing into a borehole [12]

The government regulations for sizing and design of septic tank requires that for a 20 block apartment with 2 occupants per unit, the capacity should be 2400 L per day which would mean about 3 m deep by 1.5 m which make it easier to maintain when inspecting to check and repair cracks in the impermeable concrete lining or wall, which would cause sludge to leak, or even the efficiency of sludge suction pumps due to high head or depth [13]. Improper use of the septic tanks by disposing of hazardous wastes containing heavy metals or highly acidic waste that lowers the pH, making the free ions mobile in solution, combined with poor design and poor maintenance makes the use of septic tanks risky to the groundwater [13].

II. Materials and Methodology

1) The Study Area

The study area, Ongata Rongai, (Figure 2), sits on an area of 16.5 km^2 and has 60,184 households with a total of 178,795 people [14]. It is found at 50 km from Kajiado County headquarters and 20 km from Nairobi County Central Business District (CBD) along the Langata-Magadi road. It lies approximately at latitude (0° 53' 60'' S) and longitude (36° 25' 60'' E) (Table 1).

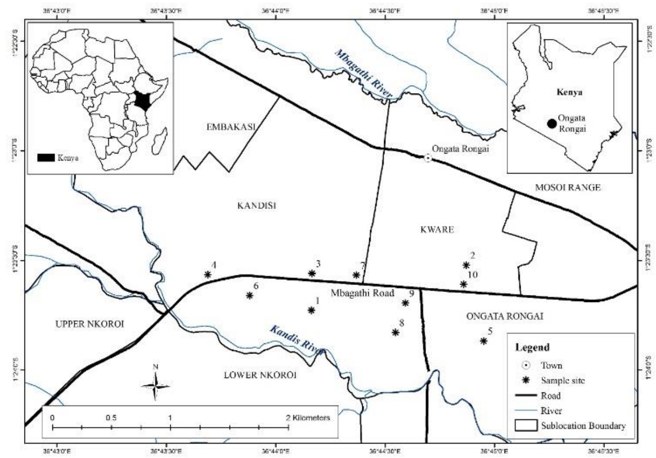

Figure 2: Map showing selected borehole sampling sites in Ongata Rongai

The Sampling Site selection

The sampling sites (Table 1) and coordinates for the selected boreholes, following a cadastral map of Ongata Rongai town, along Magadi Road, based on the socio-economic classification and population density, was recorded by a hand-held Global Positioning System (GPS) receiver (Map 410 Magellan). A total of 10 boreholes in the study area (Figure 2) located next to the septic tanks sewage disposal systems (≤ 200 m) were selected for water sampling in dry (March) and wet (May) seasons in 2019. The baseline data (Table 2) from [15] provided useful information on depth, water rest levels and yield at the time of drilling the boreholes before water sampling was done. The determination and recording of the distance between each borehole and the septic tanks was also done.

Table 1: Sampling sites GIS location and a description of the surrounding area

Site No.	**Altitude (m)**	Coordinates	**Description of sampling sites surroundings**
1	1788	01^0 23’ 42” S 36^0 45’ 49” E	Muslim mosque with borehole. The very densely populated area near a slaughterhouse. Surrounded by flats. One Septic tank at 30 m and an abandoned horticulture farm nearby.
2	1794	01^0 23’ 45” S 36^0 43’ 40” E	New life mission. Borehole at the slope. Densely populated shopping centre. Septic tanks at about 33 m
3	1793	01^0 28’ 45” S 36^0 45’ 49” E	Near the shopping centre. Heavy water abstraction for sale. Medium population
4	1780	01^0 25’ 40” S 36^0 23’ 36” E	Mbathi’s house. The borehole has been in use for 15 years. Homestead at a higher side of property’s slope, Septic tank at about 31m
5	1788	02^0 00’ 06” S 37^0 26’ 18” E	Borehole along the chief’s camp. Densely populated, septic tanks at about 15 m
6	1781	02^0 03’ 00” S 37^0 23’ 00” E	Three flats with fifty houses each. The borehole is within the compound of the flat. Septic tanks at about 120 m

7	1791	01^0 38’ 56” S 36^0 44’ 34” E	Muslim mosque and a slaughterhouse nearby in a densely populated area. River 70 m at the bottom of the slope. Mean septic tanks at about 16m
8	1790	01^0 28’ 24” S 36^0 31’ 23” E	Gather's house, with borehole. In a low-density area with bigger plot size homesteads. On flat ground, Septic tank at about 33m
9	1781	02^0 08’ 21” S 37^0 00’ 06” E	Albanus apartments, Borehole next to a flat of 60 houses. One big capacity Septic tank at about 32 m
10	1776	01^0 18’ 30” E 36^0 41’ 22” S	Ndungu Ole kapara borehole in a remote area. Septic tanks at about 146 m

Baseline information on the borehole water sampling sites

The baseline information that guided in selecting the study sites is given in Table 2. The borehole serial numbers were from the previous study [15] which was retrieved and recorded from national datum of registered boreholes, from the ministry of water and irrigation in the year 2012. These serial numbers were coded by single digits as borehole site numbers as described in Table 2 and for convenience of data handling. The water rest level was the measured height of how high the groundwater rises and rests in the borehole, based on groundwater hydrostatic pressure mainly used to determine the size and depth of pump installations. This data was also retrieved from the ministry of water and irrigation.

Table 2. Baseline data on boreholes water and their distance from the septic tanks

Borehole serial number	6231	9262	9262	13435	10663	13850	13732	19870	19653	20944
Borehole Site	1	2	3	4	5	6	7	8	9	10
Water rest level (m)	30	20.3	48	51	27	67	43	116	23	50
Borehole depth (m)	210	80	178	234	94	296	162	286	130	160
Yield (m^3hr^{-1})	6	12	13	10.6	12.6	9.8	12	10.3	10	9
Septic tank number	The distance of the septic tank from the borehole’s sampling sites (m)									
A	30	25	24	6	9	30	15	15	15	60
B	40	20	50	7	12	110	15	30	15	120
C	50	20	70	9	15	110	15	30	30	150
D	50	40	70	25	15	150	15	40	40	190
E	140	60	90	110	30	200	20	50	60	210
Mean distance (m)	63	33	60.8	31.4	16.2	120	16	33	32	146

Baseline data on boreholes water and their distance from the septic tanks [15]

The borehole depth, in meters, was the actual drilled or dug depth, from top to bottom of the borehole. The data was retrieved from the ministry of water and irrigation. The yield, in cubic meters per hour, was the quantity of water that could be abstracted from the borehole as a function of time, until the well ran dry, before the next recharge. This was done using a standard, calibrated submersible pump after drilling. The yield was dynamic depending on the number of boreholes pumped within the same aquifer and also affects the water rest level. The data was retrieved from the ministry of water and irrigation. The letters A, B, C, D, and E represented the five nearest septic tanks within minimum radial distances from the borehole sites under investigation. The mean borehole-septic tanks spatial distances in Table 2 were used

Chemicals and reagents

Stock solutions of each of 1000ppm of zinc, lead, cadmium, chromium, and manganese standards were prepared from heating metal reagents (99.9%) while mercury was obtained from $HgCl_2$, salt. Analytical quality chemicals and reagents were used; they were obtained from BDH laboratory reagents, (Ltd Poole England). Cleaning of glassware and plastic apparatus ware was done thrice with deionized water and then immersed in 20% nitric acid overnight. The apparatus were then rinsed thrice with deionized water and dried in Mermert oven.

Instrumental and apparatus

A hand-held Global Positioning System (GPS) receiver (Map 410 Magellan) was used to obtain the coordinates of the sampling sites. Analytical balance (Sartorius 1213 MP model), water deionizer (Ionizer Mk 8), Mermert Oven, Flame Atomic Absorption Spectrophotometer (Perkin Elmer 2380) and sampling plastic containers were used. The apparatus used include; sampling 2.0 L plastic containers, 50 ml, 250 ml beakers, measuring cylinder 10 ml and 100ml, volumetric flask 50 ml, 100 ml, and 1000ml and watch glass.

Sample collection

Surveys and familiarization with sampling sites were done (Figure 2) in January 2019, by visiting various borehole owners to seek their consent. Sampling was done in March and May, 2019 representing the dry and wet seasons respectively. Samples were collected in May and March accounted for the seasonal variations; May is the wet while March being the dry season. Water samples were obtained from the selected ten borehole sites (Figure 2) a representative of the Ongata Rongai area for the dry and wet seasons. Water sampling was done using the [16] which covers the standard methods for the examination of waters and wastewaters as well as water quality sampling by opening the tap at each sampling site, draining out the water for 1minute. Samples from ten boreholes sites in Ongata Rongai area were taken in pre-cleaned 2.0 L plastic containers for physico-chemical parameters and heavy metal analysis, each sample was labeled and kept in polyurethane cool boxes then transported to the Cropnut Laboratory, Nairobi, for analysis. On-site data and observation and the description of surroundings of the sampling sites were documented (Table 1) that include the exact water resource location, weather conditions at the time of sampling. It was observed that galvanized zinc pipes were used for water piping. Laboratory tests were done according to [16]. Care was taken to ascertain that the samples were truly representing the existing conditions in the study area.

Acid digestion for the analysis of heavy metals

The water samples were obtained from ten sites (Table 1) for the selected ten boreholes were acid digested as recommended by the standard procedure [17], to each 100 ml triplicate water sample in a pre-cleaned 250 ml beaker, 25 ml of 10% hydrochloric (2.5 ml concentrated hydrochloric acid + 22.5 ml distilled deionized water) was added to the beaker and heated on a hot plate. The solution was boiled until 10-15 ml was left. 10 ml of perchloric acid was added and the solution was heated until perchloric fumes evolved (observed). The remaining sample was put in a 100ml volumetric flask and topped to the mark. The solution was then shaken well and transferred into a clean sampling bottle awaiting analysis by AAS. The samples were prepared in triplicates from every site.

Preparation of heavy metal standard stock solutions and calibration curves

The following standard stock solutions were prepared for the heavy metal analysis. 1000 mgl^{-1} of zinc (Zn), lead (Pb) and Cadmium (Cd) stack solutions were prepared by heating 1.0g of the metals (99.9%) and dissolving it in 30 ml (1:1 v/v) of water: nitric acid solution then transferring the solution to 1000 ml volumetric flask. 1000 mgl^{-1} of mercury (Hg) standard stock solution was prepared by dissolving 1.354g of analytical grade salt of $HgCl_2$ (99.9%). These solutions were dissolved in distilled deionized water and diluting to the mark while 1000 mgl^{-1} of manganese (Mn) and Chromium (Cr) of ion standard stock solutions were prepared by heating 1.0g of the metals (99.9%) and dissolved in 20ml of aqua regia and diluted to 1 litre. The calibration standard curves for each metal ion was prepared by diluting 1000 mgl^{-1} stock solution to the required range.

Quality control assurance

Quality assurance control was ascertained by analysis of blank solutions. The quality control was carried out as recommended by [18] analysis of laboratory reagent and fortified blanks, as well as samples as an ongoing measurement of performance. Rinsed blanks and calibration of six standard solutions of all monitored analytes were prepared at parts per million (ppm) or parts per billion (ppb) concentration ranges for the various analytes.

Analysis of the heavy metals with Atomic Absorption Spectrometry (AAS)

Samples were analyzed by direct absorption, except for mercury which was done by cold vapor generation in a special accessory. The samples were analyzed in triplicates to minimize errors. The Flame Atomic Absorption Spectroscopy (FAAS) was warmed up and the recommended wavelengths and flame/gas types set for the various heavy metals analysis as shown in Table 3.

Table 3 Atomic Absorption Spectrometry wavelengths and flame gas used for heavy metal analysis

Element	**Wavelength (nm)**	**Flame/ gases**
Zinc	213.9	air/acetylene
Lead	217.0/ 283.3	air/acetylene
Mercury	253.7	Cold vapour generation
Manganese	279.5	air/acetylene
Cadmium	228.8	air/acetylene
Chromium	357.9	air/acetylene

The heavy metals: Zinc (Zn), Lead (Pb), Mercury (Hg), Manganese (Mn), Cadmium (Cd), and Chromium (Cr), and were determined by Perkin Elmer 2380 Flame Atomic Absorption Spectrophotometer. Procedures by [18] were followed during preparation of samples to be analyzed. The operating manual was used to give guidance setting up and optimization of the instrument and air- acetylene mixture was used as source of flame. However, for the determination of Hg, hydride generation method was used. The samples were all analyzes in triplicate and the wavelengths for the determination of each metal are shown in Table 3.

III. RESULTS AND DISCUSSION

Table 4 shows the levels of the heavy metal ions in water samples in dry and wet seasons

Table 4 : Concentrations of selected heavy metals in 10 samples sites in dry and wet seasons

Heavy metal level						
Dry Season						
Site	**Zinc** (mgl^{-1})	**Lead** (mgl^{-1})	**Mercury** (mgl^{-1})	**Manganese** (mgl^{-1})	**Cadmium** (mgl^{-1})	**Chromium** (mgl^{-1})
1	0.16±0.01	0.22±0.02	0.0017±0.0002	0.12±0.00	BDL	BDL
2	0.73±0.01	0.33±0.01	0.0017±0.0001	0.09±0.01	BDL	BDL
3	0.16±0.02	0.22±0.01	0.0018±0.0003	0.22±0.00	BDL	BDL
4	0.32±0.00	0.30±0.02	0.0019±0.0001	0.19±0.01	BDL	BDL
5	0.51±0.01	0.42±0.011	0.0017±0.0001	0.26±0.001	BDL	BDL
6	0.21±0.01	0.24±0.01	0.0016±0.0001	0.18±0.01	BDL	BDL
7	0.11±0.02	0.22±0.00	0.0013±0.0002	0.05±0.01	BDL	BDL
8	0.68±0.01	0.24±0.01	0.0010±0.0001	0.13±0.00	BDL	BDL
9	0.14±0.01	0.25±0.02	0.0017±0.0001	0.07±0.01	BDL	BDL
10	0.12±0.00	0.23±0.02	0.0002±0.0001	0.03±0.01	BDL	BDL
Wet season						
1	0.03±0.01	0.21±0.01	0.0017±0.0002	0.17±0.01	BDL	BDL
2	BDL	0.25±0.01	0.0016±0.0002	0.11±0.01	BDL	BDL
3	0.18±0.01	0.27±0.00	0.0018±0.0001	0.20±0.00	BDL	BDL
4	BDL	0.26±0.01	0.0016±0.0001	0.19±0.02	BDL	BDL
5	BDL	0.29±0.01	0.0010±0.0002	0.26±0.001	BDL	BDL
6	BDL	0.25±0.01	0.0006±0.0002	0.18±0.01	BDL	BDL
7	BDL	0.28±0.02	0.0006±0.0001	0.04±0.01	BDL	BDL
8	BDL	0.29±0.01	0.0005±0.0002	0.12±0.01	BDL	BDL
9	0.05±0.01	0.26±0.01	0.0019±0.0001	0.07±0.02	BDL	BDL
10	0.03±0.01	0.25±0.01	0.0004±0.0001	0.04±0.00	BDL	BDL
LOD	0.01	0.001	0.001	0.0001	0.001	0.005
Recommended values in drinking water						
WHO	3.0	0.01	0.006	0.01	0.003	0.05
KEBS	5.0	0.05	0.001	0.01	0.005	0.05

The recommended heavy metal values were obtained from WHO (2008) and KS EAS 153: 2014.

Effects of septic tank distances on the levels of heavy metals

Zinc levels were higher in dry season in Site 2 (0.73± 0.01 mgl^{-1}) and lower in 7 (0.11± 0.02 mgl^{-1}) (Table 4), with mean septic tanks distance of 33 m and 16 m from the borehole respectively (Table 2) while the highest and lowest levels in wet season were from Sites 3 (0.18 ± 0.01 mgl^{-1}) and 1 (0.03 ± 0.01 mgl^{-1}) with tanks mean distant at 60.8 m and 63 m respectively . In the wet season, Zinc was below detectable limit (BDL) of 0.01 mgl^{-1} at Sites 2, 4, 5, 6, 7 and 8 that were at septic tank distances between 16m and 120m (Table 2). Figure 3 shows levels of zinc in water sample in dry and wet seasons

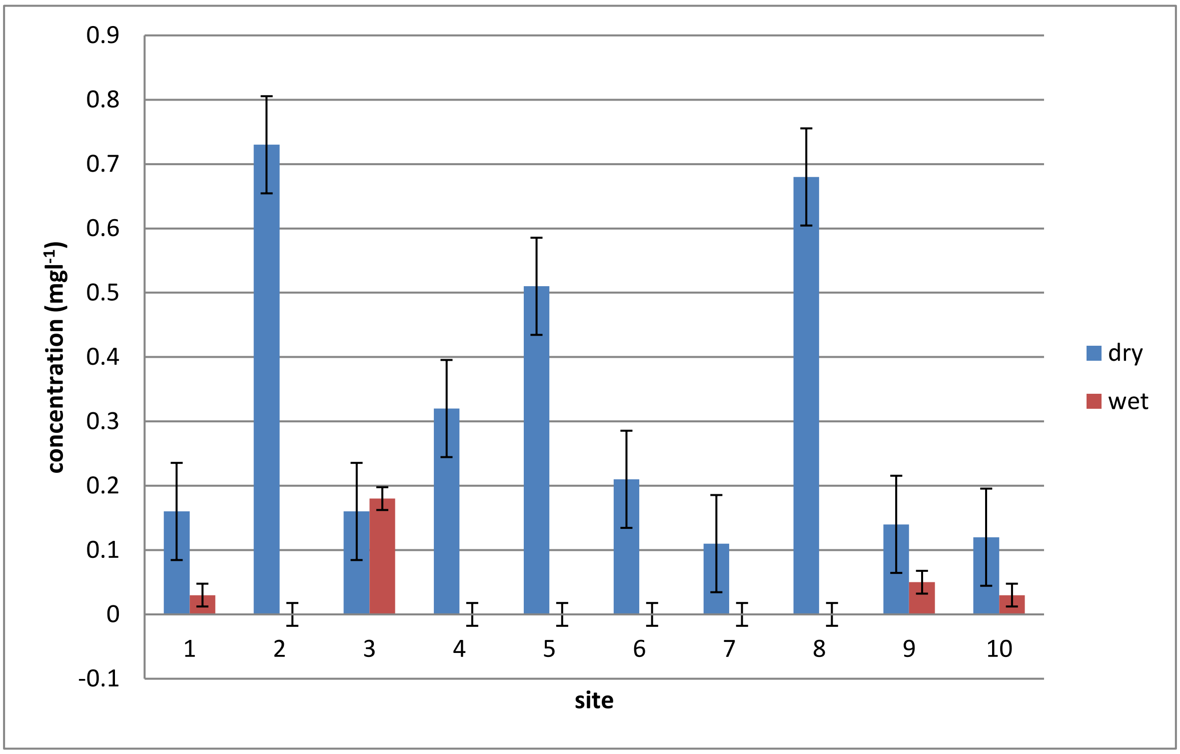

Figure 3: Zinc levels in ten borehole water samples

Zinc levels were high in dry season, probably due to the use of zinc galvanized pipe which cause corrosion therefore, causing significant zinc levels but lower in wet due to dilution process [7]. The level of zinc in the dry season was maximum in borehole Site 3 situated in area near the shopping centre that has heavy water abstraction for sale, medium population and septic tank at 33 m away. Zinc sources are from galvanized pipes used. Though zinc is naturally found in nature, there are also anthropogenic sources, for example the minimum distances from septic tanks and household products containing zinc oxide and zinc sulfide such as disposal of zinc chloride batteries [4]. Zinc oxide is used to make various products including make-up, prescription drugs and including other dietary sources present in human feces, could avail zinc into borehole water from the septic tanks. The selected boreholes sites were all constructed with a 4 inch (diameter) steel casing and 2 inch galvanized pipes immersed below the water rest level to the pump. The intimate contact, in pH<7, likely anions present and dissolved oxygen >1ppm, makes the water corrosive (pourbiax relation), and likely to avail zinc ions in water [5]. [19] has listed fever, nausea, vomiting, stomach cramps, and diarrhea as some of the health complications caused by Zinc poisoning. The mean septic tank distance did not contribute much to the levels of Zn in the water samples

The lead was observed in all water samples with the highest values in Site 5 in both dry and wet seasons at 0.42 ±0.011 mgl^{-1} and 0.27±0.00 mgl^{-1} respectively (Table 4). The mean septic tanks distance from Site 5 was 16.2 m, however, septic tanks A and B are within 9m and 12m respectively (Table 2). The lowest levels were recorded in site 1 at 63 m in both dry and wet seasons (Figure 4). Generally, the boreholes near the septic tanks (Table 2) had higher levels of Pb (Table 4). The levels were above recommended levels by WHO of 0.1 mgl^{-1} but within KEBS levels in both dry and wet seasons at, 0.1 and 0.5 mgl^{-1} respectively.

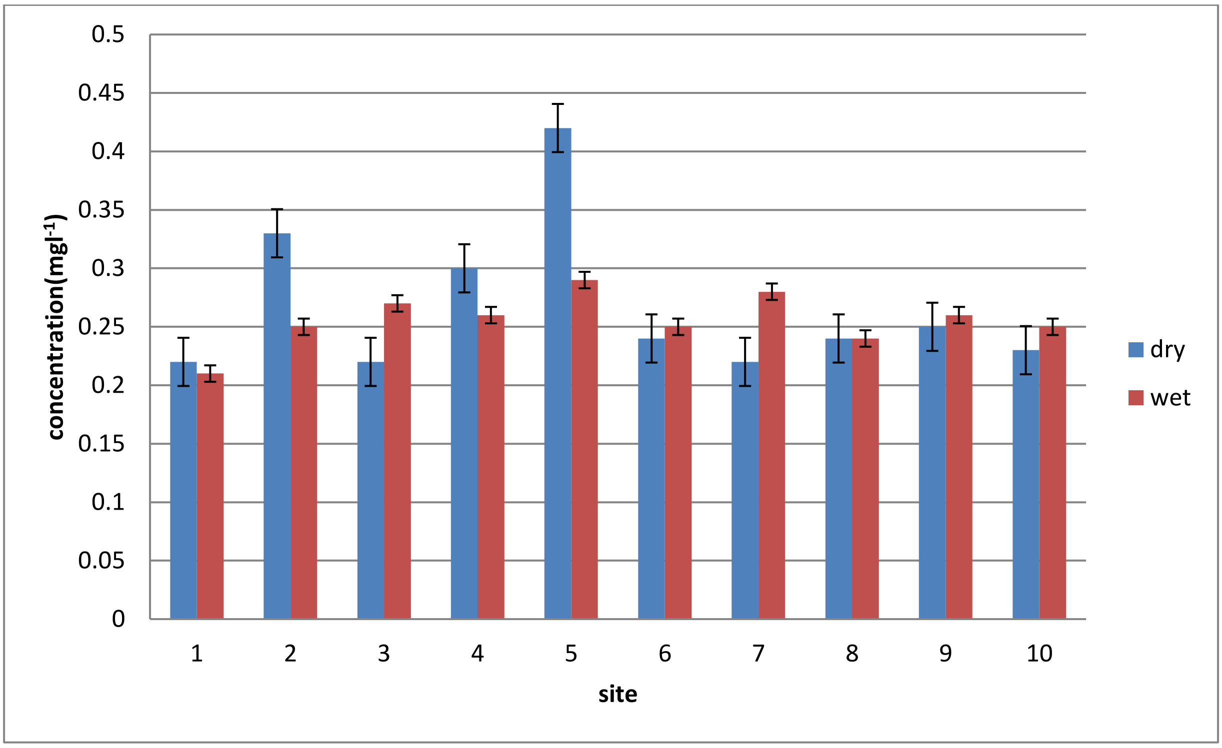

Figure 4: Lead levels in ten borehole water samples

The lead levels were higher in Site 5 in dry and wet seasons (Figure 4). Site 5 is a borehole along the chief's camp, densely populated (Table 1), the septic tanks mean distance was at about 16.2 m, in this densely populated site there was no elaborate waste disposal as well as waste management practices in the area . The septic tank waste disposal was not entirely effective, the waste may leak and contaminate groundwater. The lead-in water samples were in the minimum range of 0.220± 0. 010 mgl^{-1} to a maximum of 0.42 ±0.01 mgl^{-1} during the dry and with a minimum range of 0.28 ± 0.02 to a maximum of 0.29 ± 0.01 mgl^{-1} in the wet seasons (Table 4.3). However the baseline data for lead values were not available for comparison, but the availability of lead in water, shows that it is likely that human activity has had an accumulative effect to reach this level probably as a result of disposal of lead ions from human activity e.g. fecal matter containing trace levels of lead over time. [8] [20] in his study suggested that the use of leaded petrol in cars, generators and even some mechanic workshops especially battery charging at the chiefs camp could contribute to contamination of borehole water by lead. In the study, the distance of septic tanks on levels of lead, had little significance. Great attention should be paid to levels of lead, it has been found that lead is carcinogenic [20].

Site 10 at a mean septic tank distance of 146 m had the lowest levels of Hg in both the dry and wet seasons (Figure 5). Mercury levels were at 0.0002 ±0.0001 mgl^{-1} and 0.0004 ±0.0001 mgl^{-1} in dry and wet seasons respectively (Table 4). Sites 4 and 9 at close mean distances of 31.4 m and 33 m respectively had the highest levels of Hg at 0.0019 ±0.0001 mgl^{-1} during the dry and wet seasons respectively, which were slightly above the

KEBS recommended levels of 0.001 mgl^{-1} but were within WHO levels of 0.006 mgl^{-11} (Table 4). It was observed that boreholes that were closer to the septic tanks had higher levels of mercury in both dry and wet seasons. These levels were within recommended value by WHO of 0.006 mgl^{-1} (Table 4).
Mercury was present in all water samples analyzed (Figure 5). Site 4 at Mbathi's house with a borehole which has been in use for 15 years had the highest level in dry season. The homestead is at a higher side of property's slope and septic tank mean distance of 31m. Site 9 is at Albanus apartments, borehole next to a flat of 60 houses there is one big capacity septic tank at about 32 m (Table 2), mercury from cosmetics products from wastewater and feces from Mbathi's and 60 houses deposited in septic tank contaminate water from the boreholes at level slightly higher than KEBS but within WHO recommended (Table 4). . In the study, the distance of septic tanks on levels of lead, had little significance. These levels of mercury cannot be overlooked due to its effects on the kidney, central nervous system and physically deformed babies [4].

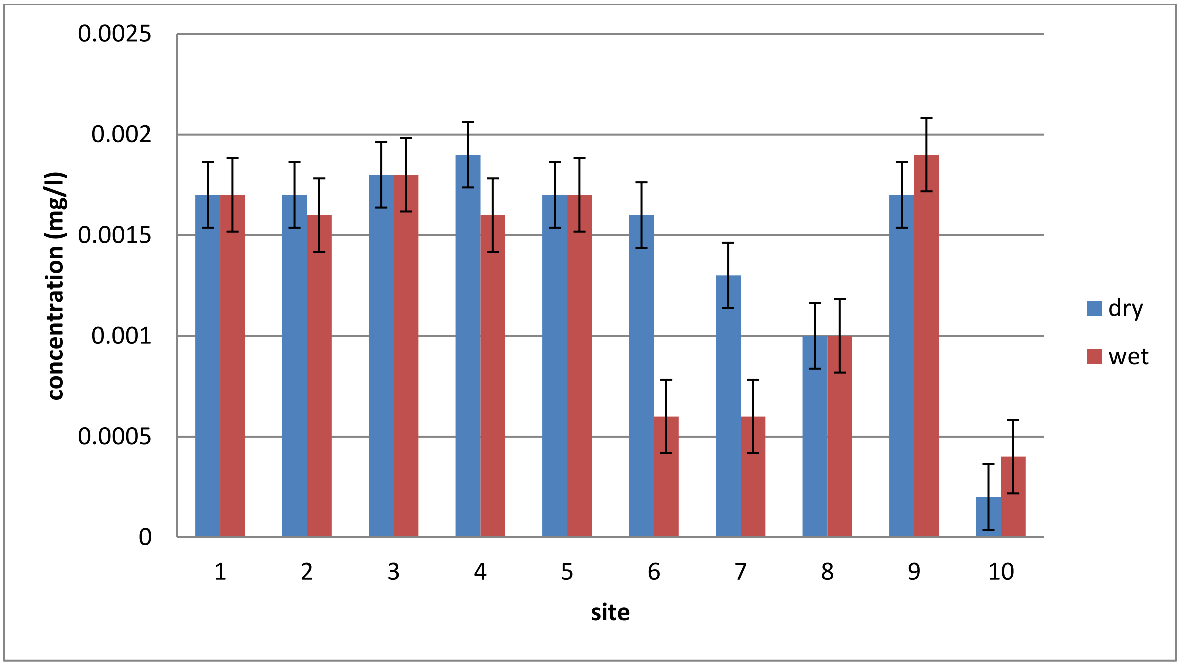

Figure 5: Mercury levels in ten borehole water samples

The highest levels of Manganese (Mn) were in site 5 at 16.2 m (Table 2) in both dry and wet seasons, at 0.26 ±0.0012 mgl^{-1} (Table 4). Site 10 at a mean distance of 146 m recorded the least levels in both dry and wet seasons (Figure 6). It was observed that Sites 5 at nearby mean septic tanks distance of 16.2 m had higher levels of manganese as compared to the ones far way in dry season. Also, Mn levels were higher in all sites as compared to the levels recommended by WHO and KEBS of 0.01 mgl^{-1}.
Manganese levels were generally higher in all the samples (Table 2) than the recommended levels of 0.01 mgl^{-1} by WHO, KEBS and NEMA in drinking water (Table 2). Site 10 is Ndungu Ole Kapara borehole in a remote area with low population that may not contaminate the water. This could be attributed to high presence of manganese in rocks or soil in the area. Site 5 borehole is at the chief's camp in a densely populated area that can cause water contamination. Site 7 is a Muslim mosque and a slaughterhouse nearby in a densely populated area (Table 1) that may cause water contamination. According to [21] slaughterhouses are a significant source of water pollution and some of impacts include: release of highly polluted effluent containing blood and feacal

matter which may find its way to water sources. Densely populated areas suffer from strain on available amenities that includes waste disposal systems and water [13]. Some of health effects caused by Manganese include; hallucinations, Forgetfulness, nerve damage, Parkinson disease, Lung embolism and bronchitis [4].

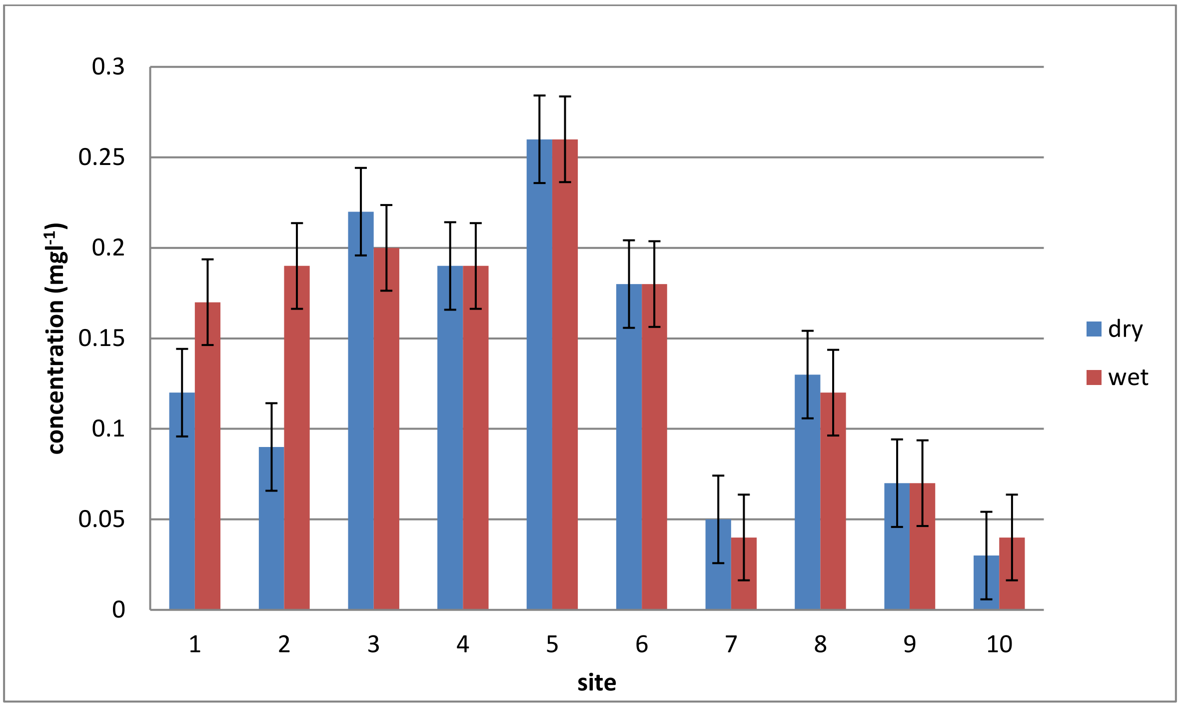

Figure 6: Manganese levels in water samples

The quantities of cadmium (Cd) and chromium (Cr) were below detectable limits of 0.001 mgl^{-1} and 0.005 mgl^{-1} irrespective in boreholes water from the septic tanks in all the sites during both dry and wet season (Table 4). Cadmium and chromium were found to below detectable limits, could be due to minimum human activities that raise the levels e.g., agrochemicals, some fertilizers containing Cd as impurities, especially phosphate fertilizers in fecal matter containing phosphate from consumed food had no influence on Cd and Cr residue levels in water. The poisonous species, hexavalent chromium, is highly soluble and easily moves within the environment [22] was not observed; which was not evident in the area at the time of the study. The water samples are free from Cd and Cr contamination therefore safe for human consumption as they were below the recommended values by WHO and KEBS of 0.003 mgl^{-1} and 0.005 mgl^{-1} for Cd while Cr at 0.05 mgl^{-1} for all the two bodies respectively (Table 4). Cadmium and hexavalent form of chromium has been found to be carcinogenic [23] and [24]. Cadmium was found to cause anemia and even hepatic disorders [22].

High concentrations of some of the metals observed in the wet season samples could be an indication that the soluble forms of the metals are either present in the environment or produced after chemical reaction have occurred this is consistent to a study done by [25]. This study concurs with [26] that there is a need to educate property owners on the importance of groundwater protection and also regular borehole water quality monitoring because the residents depend on the same boreholes for domestic water uses.

IV.CONCLUSIONS

The proximity of the boreholes to the mean septic tanks distance had a significant effect on the levels of lead, mercury and manganese but had no effects on the levels of zinc, cadmium and chromium in the borehole water samples. Boreholes closer to the septic tanks showed higher levels of heavy metal as compared to the ones far away but these levels were below the recommended values by WHO and KEBS.

It was also observed that human activities had a huge influence on the quality of water for instance Site 5 was in a densely populated area and had four septic tanks within the 15m radius had high levels of heavy metals.

Manganese levels were generally higher in all the samples than the recommended levels of 0.01 mgl^{-1} and 0.03 mgl^{-1} by WHO and KEBS in drinking water respectively except Site 10 where the value was within the recommended level of 0.03 mgl^{-1} of KEBS limits of manganese in the dry season. The cadmium and chromium levels were below detectable limits (BDL) in both the seasons for all the borehole water samples analyzed, do not cause any health threat to human and environment

The results showed there was stronger relationship between the distance of borehole from septic tanks and some heavy metal levels e.g. Lead, mercury and Manganese.

V. RECOMMENDATIONS

Regular analysis of the heavy metals in borehole water to be conducted due to their accumulation nature with time.

WARMA to document the number of boreholes in the area and to provide guidelines on setting up new ones.

The source of highly toxic metals like lead, and mercury in water be investigated further. Pesticide residues levels should be investigated in borehole water samples

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