

Assessment of Dissolved Ions and Microbial Coliform in Water from Selected Sites of the Upper Athi River Sub-Catchment Area, Kenya.

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Abstract : Twenty one water samples were collected and analysed for dissolved ions and microbial coliforms from selected sites of the Upper Athi River sub-catchment basin. The metal ions analysed included Ca, Cd, Cr, Cu, Fe, Mg, Mn, Na, Pb and Zn while anions included Cl⁻, CO₃²⁻/HCO₃⁻, F⁻, NO₂⁻/NO₃⁻ and SO₄²⁻ as well as faecal coliforms. Physical parameters analysed included pH, electrical conductivity (EC) turbidity, total dissolved solids and colour. The analysis was carried out using atomic absorption spectrophotometry, titrimetric, ion selective electrode, gravimetric and lactose broth methods. The results showed that levels of dissolved ions in ground water were higher than in surface water while surface water had higher number of faecal coliforms. The high levels of dissolved ions in ground water was attributed to the geology of area while high levels of iron and faecal coliforms in river water samples was attributed to anthropogenic activities

Keywords: Anions, coliforms, ground water, heavy metals, Upper Athi

I. Introduction

Clean and safe drinking water is vital to health as well as a basic constitutional right [1]. Safe drinking water is one that does not contain disease-causing micro-organisms, or toxic heavy metals that could cause bioaccumulation when such water is used over a long duration of time. Children and the elderly are particularly the most vulnerable groups from effects of using unsafe drinking water [2]. There is increasing demand for safe drinking water as the world population continues to increase in the backdrop of inadequate fresh drinkable water in many parts of the world [3]. For meaningful prosperity to be realized clean and safe drinking water that is readily available should be the point of focus by governments and local authorities according to water quality assessment of 2007 by the Ministry of Water and irrigation [2].

Sustaining sufficient water supplies for domestic, agricultural and industrial use would be impossible without groundwater which is the largest and most reliable of all freshwater resources since it is being used by about two billion people worldwide; making it the most important natural resource [2]. By estimates the world is producing between 9087 billion m³ of water annually [4]. Kenya in particular faces acute water shortage both in urban and many rural areas. Of particular concern is the ever growing urban population especially in Nairobi [5]. Several up-coming residential areas around Nairobi are not supplied with safe drinking water from the licensed water companies [5]. This has forced residents of these areas to explore other possibilities such as digging shallow wells and drilling bore-holes in order to access water for domestic purpose [5]. Whereas ground water has become a panacea to many families, institutions and companies, its suitability has not been ascertained. Comprehensive studies in several areas of Athi basin in Kenya (see fig.1) have not been done to establish whether the groundwater meets the safety standards for human and animal consumption. Therefore, human population in areas whose ground water quality is not known faces a risk of illness such as osteomalacia and fluorosis caused by high levels of dissolved ions [6]. This study was therefore to assess the residue levels of various cations, anions and coliform bacteria in ground and surface waters in selected areas of upper Athi River basin and compare them with world health organization (WHO) and Kenya bureau of standard (KEBS) specifications levels for drinking water.

II. Materials And Methods

2.1 The Study Area

The study area (Figure 1) is located in the East-Southeast of Kenya and lies between latitude 1° 15' to 1° 30'S and longitude 36° 39' to 37° 05'E. The area stretches about 45km along the Upper Athi Sub-catchment area. The area is rapidly growing in terms of human population and therefore ground water in form of shallow wells and boreholes has become an essential natural resource for domestic, industrial and agricultural and livestock use [[7].

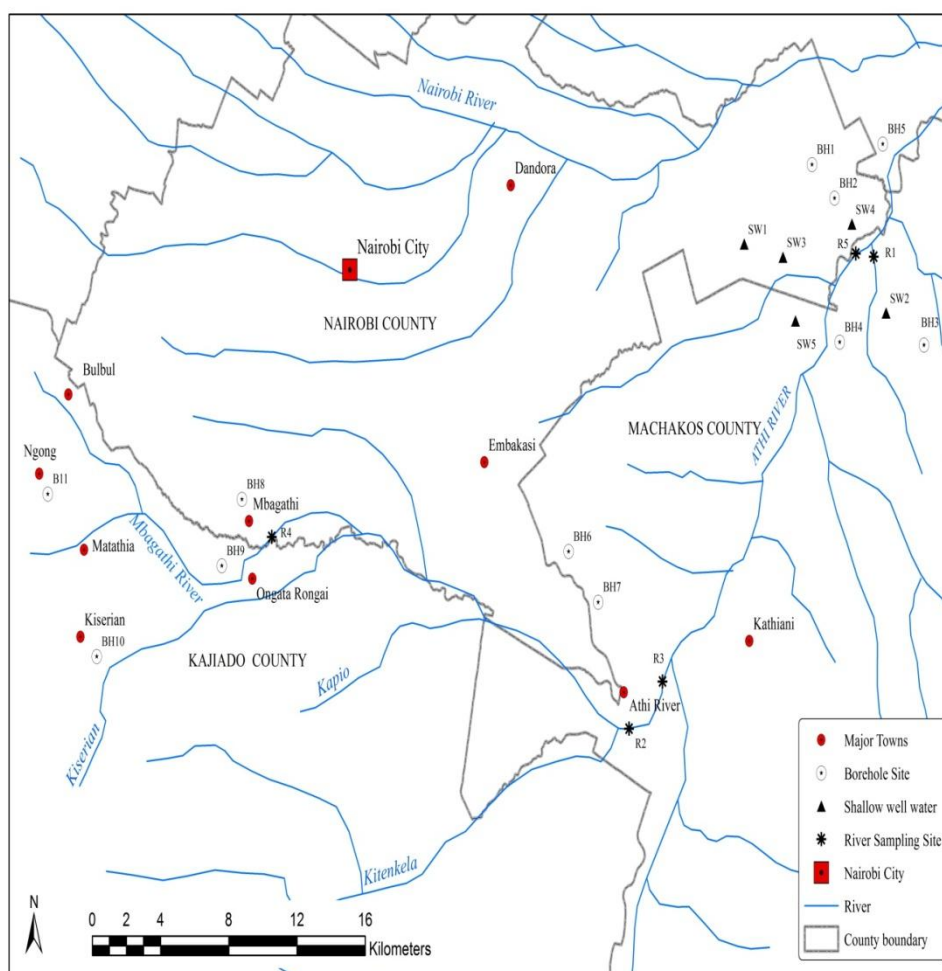


Figure 1: Map of Upper Athi River sub-catchment area showing sampling sites.

2.1 Sample collection

Twenty one samples of water were collected from selected sites ranging from boreholes, shallow wells and river using pre-cleaned polyethylene bottles. The samples were taken to the Department of Chemistry's laboratory at the University of Nairobi for analysis. Samples were collected into two seasons, in the December 2011 (dry) and May 2012 (wet). This was mainly to find these seasonal variation and human activities on the residue levels of physico-chemical parameters, dissolved ions and the number of coliform present in the water samples.

2.2 Sample Preparation and Analysis

The water samples were acid digested following methods by [5] and [6]. To each beaker, 25 ml of 10 % hydrochloric acid (2.50 ml Concentrated acid + 22.50 ml deionized water) was added. The contents were filtered through the Whatman filter paper No. 1 and filtrate collected in a 250 ml beaker. The residue in the filter paper was washed 4 times with 50 ml hot deionized water, the washings collected with the 250 ml beaker and allowed to completely cool. The solution in the 250 ml beaker was transferred into correspondingly labelled 250 ml volumetric flasks. The beaker was rinsed and volume of the solution in the 250 ml volumetric flask made to the mark with the deionized water.

2.2.1 Analysis of chloride.

200ml of the water sample was transferred into a 400ml beaker. 5ml of concentrated nitric acid was added to neutralize calcium carbonate until no reaction further occurred. The solution was boiled for 5 minutes and then filtered through Whatman filter paper No.1(150mm). 100ml of the solution was pipetted in a porcelain dish. 1ml of potassium dichromate (K_2CrO_4) indicator solution was added and well mixed. The solution was then titrated against N/10 silver nitrate ($AgNO_3$) solution until the colour changed from yellow to brown. The readings of silver nitrate was recorded as procedure was repeated twice to obtain consistent results for all the samples.

Calculations

Chloride as Cl ppm = (ml AgNO₃ sample - ml AgNO₃ blank) x normality of AgNO₃ x 10 x 35.5

2.2.2 Potentiometric determination of fluorides

The fluoride was determined potentiometrically using a Fluoride ion meter by dipping the fluoride electrode meter into 50 ml of the sample and taking the levels of fluoride in the sample the analysis was carried out at the Central water testing laboratory, at the Ministry of Water

2.2.3 Determination of total alkalinity of carbonate and bicarbonate using Titration method

100ml of the water sample was measured and transferred into a porcelain boat. 2 drops of phenolphthalein indicator was added. The mixture was titrated slowly using 0.1N hydrochloric acid (HCl) while stirring gently with a glass rod until the colour just disappeared. The volume of the acid used was recorded. To the same sample, 2 drops of methyl orange indicator was added. The sample was further titrated slowly using 0.1N HCl till colour change from yellow was noted. The total volume of the acid used was recorded and the procedure was repeated twice for consistency for all the samples.

Calculations

Alkalinity to phenolphthalein as mg/ 1ml (ppm) CaCO₃ = X (ml of N/10 HCl) x 5 x 1000

ml of the sample taken (1 ml N/10 HCl = 5mg CaCO₃)

Alkalinity to methyl orange mg/l (ppm) CaCO₃

= Y (ml of N/10 HCl) x 5 x 1000 ml of the sample taken

Total alkalinity = alkalinity to phenolphthalein + alkalinity to methyl orange

2.2.4 Gravimetric determination of sulphate ions

100ml of water sample was pipetted into 250ml beaker and 2ml 1:1 HCl was added. The mixture was boiled while adding an excess 10% (10g BaCl₂.2H₂O in 100ml distilled water) solution slowly while stirring. The precipitate was digested for 2 hours at 80°C on the hot plate. The precipitate was then filtered through Whatman filter paper No. 542 and wash with warmed distilled water till free from chloride (tested with AgNO₃ solution). The residue was dried and ignited at 800°C to constant weight and the procedure was repeated for all the samples.

Calculating the Sulphate content; SO₄²⁻ ppm = weight of residue in mg x 0.4115 x 10

2.2.5 Analysis of metal ions using atomic absorption spectrometer

Analysis of metal ions was done using atomic absorption spectrophotometer, (Model AAS Varian spectra AA 10) at Mines and Geology Department. 100ml of water sample was measured using a 100ml volumetric flask and then transferred into a 250ml conical flask. 10ml of concentrated nitric acid was added into the flask and stirred. The mixture was then digested at 80°C for two hours. The solution was then filtered through Whatman filter paper No. 1 into a 100ml volumetric flask and filled to the mark using distilled deionized water.

2.2.6 Analysis of Nitrates

Presence of nitrates in water samples were determined by preparing standards, that is, 0.01ppm to 20ppm from 100ppm stock potassium nitrate solution. The standards were then transferred into a beaker and 1ml of nitrate buffer (NH₄)₂SO₄ was added. The nitrate electrode was inserted into the beaker starting with the lowest standard. Then, 50ml of the sample was put into a beaker and 1 ml of buffer added. The nitrate electrode meter was inserted into the solution and the concentration was measured.

For nitrites, the formation a reddish azo dye at pH 2.0-2.5 was determined by coupling diazotized sulfanilamide with N-(1 naphthyl) ethyldiamine dihydrochloride (NED dihydrochloride). To 50ml of the sample, 2ml of colour reagent was added and mixed thoroughly. Any colour change was noted as an indication of presence of nitrite ions.

2.2.7 Analysis of total coliform and Escherichia Coliform (E. coli)

Total coliforms and *Escherichia Coliform* (*E. coli*) were analyzed by inoculating a 50ml water sample and five 10ml samples in lactose broth for 48 hours at 35°C or 37°C total coliform and 24 hours at 44°C for thermo tolerant coliform and the MPN index value was determined from specific tables to the combination of tubes and dilutions.

2.3 Statistical Data Analysis

Data analysis was done using Microsoft excel, the correlations between the seasonal variation and the level of selected cations, anions and fecal coliforms were done using Statistical Package for Social Sciences tools (SPSS). Results obtained was represented by use of text, graphs and statistical tables to show the

interrelationships of various variables such as pH, TDS, electrical conductivity (EC), turbidity, levels of selected cations, anions and Faecal coliforms in boreholes, shallow wells and river water samples.

III. Results And Discussions

3.1. Physicochemical parameters and anions in water samples of Upper Athi catchment area.

The physicochemical parameters, pH, electrical conductivity (EC), turbidity, colour, TDS, coliforms and anions in water samples of Upper Athi Rivercatchment collected in December 2011 are shown in Table 1. The pH varies from 7.24 to 9.34 with an average of 8.04. The pH is slightly neutral to weakly alkaline. The pH could be attributed to rocks in the study area that include the alkali-basalt, syenite and phonolites that have high concentration calcite minerals rich in carbonate ions [8].

Table 1: Physico-chemical and biological parameters in water samples from the shallow wells, boreholes and rivers in the upper Athi River catchment in December 2011.

Sites	pH	E.C	Turbidity	Colour	TDS	Coliforms	TotalCl ⁻	F ⁻	NO ₃ ⁻	SO ₄ ²⁻	
							Alkalinity				
SW1	8.24	813	BDL	1.70	504.26	0.00	56.41	74.11	1.67	2.98	36.14
SW2	7.81	805	BDL	1.60	499.18	0.00	43.69	65.91	2.85	3.01	75.68
SW3	8.47	832	BDL	1.90	516.63	25.00	30.11	226.49	4.26	13.45	230.76
SW4	8.16	669	BDL	1.50	415.48	0.00	36.24	96.38	3.94	8.62	41.40
SW5	9.34	943	BDL	2.70	585.79	0.00	43.65	101.27	4.32	4.73	38.57
BH1	8.49	794	BDL	0.00	508.16	0.00	52.33	111.75	4.24	2.84	69.23
BH2	7.54	891	BDL	0.00	570.24	0.00	50.65	109.23	2.45	3.05	74.65
BH3	7.78	758	BDL	0.00	485.12	0.00	48.42	70.84	3.96	2.13	101.14
BH4	8.59	840	BDL	2.70	521.35	0.00	31.73	106.56	4.02	3.29	21.40
BH5	9.34	943	13.6	46.50	585.81	0.00	64.12	96.42	4.51	1.86	65.61
BH6	8.65	975	BDL	3.20	605.64	0.00	38.98	138.58	9.36	1.77	140.80
BH7	8.47	1000	BDL	1.20	620.76	0.00	40.44	150.11	8.79	5.01	155.34
BH8	7.93	449	BDL	0.00	278.92	0.00	35.63	43.29	2.06	9.68	17.30
BH9	7.28	362	BDL	6.80	224.92	0.00	37.42	89.14	0.37	8.32	15.11
BH10	8.23	440	BDL	1.40	273.59	0.00	29.66	30.04	3.11	2.11	19.72
BH11	7.75	743	BDL	0.30	461	0.00	41.57	99.18	1.01	5.98	43.836
R1	7.32	647	81.60	226	401.24	140	8.21	33.10	0.73	7.39	506.24
R2	7.47	516	79.40	256	320.38	215	20.65	107.60	0.91	3.54	80.12
R3	7.43	463	84.40	219	287.45	294	21.02	120.30	1.02	3.92	74.74
R4	7.33	382	75.50	159	237.62	193	25.94	89.40	3.15	15.68	83.05
R5	7.24	752	74.30	198	462.71	193	10.73	90.53	1.37	11.36	520.32
Min.	7.24	362	BDL	0.00	224.92	0.00	8.21	33.1	0.37	1.77	15.11
Max	9.34	1000	84.40	256	620.76	294	64.12	226.49	9.36	15.68	520.32
Mean	8.04	715	68.50	53.78	436.37	50.48	35.55	97.63	3.24	5.748	114.81
SD	0.63	204.05	26.97	92.34	150.54	92.24	14.28	42.56	2.37	4.040	142.25

SW: Shallow wells, BH: Boreholes, R: River water, below detection limit (BDL)

Electrical conductivity ranged from 362 to 1000µS/cm in water samples collected in December 2011 (Table 1).Electrical conductivity is dependent on the type of rocks the water is in contact with and how long it takes for water to percolate into the underground aquifer [9]. Rain water which is the main source of underground water is slightly acidic and therefore tends to react with feldspar minerals mainly consisting of potassium, sodium and aluminum silicates [10]. These tend to increase levels of dissolved ions in ground water more than that of surface water[11]. Underground water had turbidity levels of below detection limit except in borehole 5 (BH5) that had turbidity values of 13.6-18.4 NTU while surface water had turbidity levels of between 74.3-95.4 NTU(Table 1). The low turbidity levels in underground water is attributed to the fact that silt sand and mud are trapped by the overlying rocks which act as a sieve such that by the time water percolates into the aquifer underground, there in insignificant levels of suspended solid particles [12]. On the other hand, surface water had higher values of turbidity due to surface run-offs that carry silt and organic matter into the streams and rivers [13]. According to WHO drinking water guidelines, drinking water should have turbidity levels of below 5 NTU [14].

The colour for underground water systems were very low, ranging from0-6-6.8 c.u apart from borehole 5 (Table 1) which had colour levels of between 46.5-51.2 c.u. Surface water on the other hand had higher colour

levels ranging from 159-343 c.u. Total dissolved solids were high in both underground and surface water in the samples collected which ranged from 224.92-620.76µS/cm during the dry season of December 2011 and 302.8-1003µS/cm during the wet season of May 2012 (Table 2). The high levels of total dissolved solids (TDS) were attributed to the geology of the area of study that had high levels of sodium, calcium, carbonates and Sulphates [15]. The WHO water drinking standards require that water which is deemed safe for drinking should have TDS levels of less than 500mg/L [15]. TDS levels above this limit make water unpalatable and has potential of being contaminated with heavy metals such as copper, iron, cadmium, lead and zinc [16].

Total coliforms were generally low in underground water ranging from 0-25 c.f.u/100ml of water in dry season of December 2011. Shallow wells had slightly higher total coliforms than the boreholes pointing to possible anthropogenic effect and the sheer depth of the shallow wells which could lead to contamination from pit latrines nearby as well as contamination from animal manure that tend to be transported to streams and rivers by surface run-offs [17].

Total alkalinity was higher in underground water compared to surface water ranging from 30.11-64.117ppm in dry season and 25.00-57.50ppm during the wet season of May 2012 while in surface water total alkalinity ranged from 6.50-25.94ppm [18] [19]. The high levels of carbonates and hydrogen carbonates was attributed to presence of carbonaceous shale in the area of study. Chloride levels were high in both underground water and surface ranging from 33.10-226.49ppm in December 2011 and 26.03-145.55ppm in May 2012. Whereas the high levels of chloride ions in underground water could be attributed to the geology of the study area, the high levels of chloride ions in surface water was astonishing pointing at a possible anthropogenic activities from point source pollution such as abattoirs that lead to high levels of chlorides finding their way into rivers and streams [20]. Chloride levels in unpolluted water systems ranges from 250mg/L. Chloride levels above this limit make water to have a detectable taste [21]. Fluoride levels were higher in underground water compared to surface water which ranged from 0.37-9.36ppm in December 2011 and 7.00ppm in May 2012. In most underground water sites sampled, fluoride levels were higher than those recommended by WHO of 1.5ppm in water for human consumption [22]. It is therefore evident that communities living in these areas where the only source of water is underground water, they are consuming water that is unfit for human consumption. Whereas fluoride levels at low concentrations is essential in the formation of enamel in children, studies have shown that daily intake of fluoride at concentration above 0.5mg/L could lead to mild dental fluorosis in children. Intake of fluoride at concentrations above 2.0mg/L could lead to severe skeletal effects [22]. Nitrates levels were higher in surface water samples as compared to underground water samples. The high levels of nitrates in surface water could be due to inorganic nitrate fertilizers or from contamination from human and animal wastes as a result of oxidation of ammonia by anaerobic bacteria and find their way into waterways through surface run-offs [23]. Sulphate levels were higher in surface water than in underground water with levels ranging from 74.735-520.321ppm and 15.11-230.763ppm respectively. The high levels of sulphates in surface water could be attributed to human activities especially from sulphonates containing detergents and industrial effluents. Whereas there is no known health risk associated with high intake of sulphates, it is recommended that drinking water should not exceed 500mg/L of sulphate it would increase the risk of gastrointestinal effects such as diarrhea [24].

Table 2. Physico-chemical and biological parameters in water samples from shallow wells, boreholes and rivers in the upper Athi River catchment in May 2012.

Sites	pH	E.C	Turbidity	Colour	TDS	Coliforms	Total Cl ⁻	F ⁻	NO ₃ ⁻	SO ₄ ²⁻	
							Alkalinity				
SW1	7.72	502	BDL	2.10	321.28	10.00	39.00	67.45	1.52	1.89	29.22
SW2	7.16	938	BDL	1.70	600.28	16.00	37.50	56.80	2.06	2.71	69.54
SW3	7.36	1568	BDL	2.00	1003.00	40.00	26.30	216.55	4.06	12.32	214.80
SW4	8.45	635	BDL	1.60	406.20	12.00	30.20	89.93	3.75	6.78	34.98
SW5	8.06	913	BDL	3.20	584.32	18.00	37.50	92.30	4.18	2.52	28.81
BH1	8.14	1001	BDL	2.10	640.64	25.00	45.00	102.95	3.87	2.20	60.49
BH2	8.03	1118	BDL	1.50	715.52	0.00	42.50	100.56	2.09	2.21	69.13
BH3	7.27	1154	BDL	2.60	738.00	0.00	41.50	67.45	2.76	1.53	91.35
BH4	7.34	1271	BDL	3.00	813.44	0.00	25.00	99.40	3.21	2.36	16.46
BH5	8.78	1146	18.40	51.20	733.41	0.00	57.50	92.30	3.73	1.74	61.73
BH6	8.29	1124	BDL	4.10	719.36	19.00	34.00	131.35	7.00	1.52	133.74
BH7	7.75	1343	BDL	1.50	859.52	0.00	35.50	145.55	6.45	4.32	148.55
BH8	7.89	741	BDL	0.40	474.24	0.00	30.20	41.46	1.84	8.38	13.58
BH9	8.52	472	BDL	7.30	302.08	0.00	30.80	85.20	0.28	7.55	11.93

BH10	8.03	540	BDL	2.20	345.60	0.00	25.00	26.03	2.62	1.98	16.46
BH11	7.98	955	BDL	1.40	611.2	0.00	35.50	95.85	0.78	5.74	39.50
R1	6.89	587	95.40	331.4	375.86	156	6.50	28.40	0.28	6.33	481.87
R2	8.00	873	86.70	343	558.72	228	16.00	99.40	0.61	2.78	63.31
R3	7.07	816	94.60	304	522.24	309	16.90	106.50	0.75	2.96	66.25
R4	6.91	1202	80.20	296	769.38	297	20.00	85.30	2.80	10.74	74.48
R5	7.80	629	78.30	327	402.56	266	8.40	81.65	1.02	7.21	493.80
Min.	6.89	472	BDL	0.40	302.08	0.00	8.40	26.03	0.28	1.52	11.93
Max.	8.78	1568	95.40	343	1003	309	57.50	216.55	7.00	12.32	493.80
Mean	7.78	929	87.04	80.44	595.08	66.48	30.51	91.06	2.55	4.56	105.71
SD	0.54	302.90	7.91	138.07	193.83	109.85	12.42	41.25	1.92	3.23	136.41

SW: Shallow wells, BH: Boreholes, R: River water, below detection limit (BDL)

3.2 Heavy metals, alkali and alkaline earth metals concentration in dry and wet seasons

Heavy metals Cd, Cr, Cu, Fe, Mn, Pb, Zn, alkali and alkaline earth metals (Na, Ca, Mg) in water collected in selected sites of the Upper Athi catchment area, Kenya are presented in Tables 3 and 4. Cadmium, chromium and copper levels were below detection level. Iron levels ranged from 0.03-18.40ppm in December 2011 (Table 3) and 0.33-14.125ppm in May 2012 (Table 4). The highest levels of iron were present in surface water. This could be attributed to human activities industrial effluents from steel making industries. At low levels iron is an essential in the formation of haemoglobin pigment in blood and iron deficiency leads to anaemia. However, high levels of iron could lead to iron toxicity thus causing haemosiderosis [25].

Manganese levels ranged from 0.02-1.27ppm (Table 3) and 0.075-0.90 ppm (Table 4), these range are above the allowed limit of 0.05mg/L in water [26]. The high level of manganese in underground water could be due to existence of rocks containing trace amounts of manganese. Excessive intake of manganese could lead to hypertension as well as tremors and stiff-neck symptoms [27]. Lead levels ranged from 0.09-0.586 ppm (Table 3) is above the allowable limit of 0.05mg/L [28]. Lead is very toxic metal even in small amounts by causing mental retardation especially in children [29]. Zinc levels ranged from 0.06-0.25ppm (Table 3) and 0.170-1.105 ppm (Table 4). At low levels zinc is an essential mineral in metabolism and in protein synthesis [30]. Sodium, calcium and magnesium levels ranged from 19.673-116.65ppm, 18.99-201.29ppm and 0.03-18.40ppm respectively. Sodium levels could be attributed to sodium bearing rock minerals where sodium dissolves in water as it percolates through them to the aquifer [31],[32]. At low levels sodium is essential in nerve impulse transmission, body fluids retention as well as muscle contraction and relaxation [33], [34]. However, high intake of sodium could lead to hypertension, heart attack and stroke [35], [36]. Calcium is found in limestone while magnesium is present in magnetite rock [37]. Calcium is an essential mineral in the body in teeth and bone formation as well as neuromuscular movements. An adult's daily intake of calcium of between 700-1000mg is recommended to prevent deficiency diseases such as osteoporosis and osteomalacia [38].

Magnesium on the other hand as a co-factor, in many enzymatic reactions such as glycolysis, ATP formation transport of K, Na and Ca [37]. Magnesium deficiency could lead to vasoconstriction of blood vessels, hypertension, and heart attacks among other health challenges [39], [40], [41]. A daily intake of 300-400mg of magnesium is recommended for an adult [38]. Therefore, both calcium and magnesium are essential elements in the body. However, it is their presence in water for laundry use that cause problems because they cause water hardness leading to more use of soap by residents of the study area as well as spoiling boilers when used in industries [42].

Table 3: Metal ions concentration in water samples from shallow wells, boreholes and rivers in the upper Athi River catchment in December 2011

Sites	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Na	Pb	Zn	
SW 1	50.43	BDL	BDL	BDL	0.43	3.78	BDL	80.43	BDL	BDL	
SW 2	44.75	BDL	0.01	BDL	0.45	9.03	BDL	73.28	0.23	BDL	
SW 3	201.29	BDL	BDL	BDL	0.33	11.65	BDL	91.75	0.21	0.06	
SW 4	170.81	BDL	BDL	BDL	0.75	10.98	BDL	56.63	0.19	BDL	
SW 5	20.36	BDL	BDL	BDL	0.70	5.44	BDL	34.67	0.13	BDL	
BH 1	30.41	BDL	BDL	BDL	0.33	6.14	BDL	71.26	0.14	BDL	
BH 2	41.26	BDL	0.01	BDL	1.58	7.89	BDL	94.34	0.31	0.12	
BH 3	28.79	BDL	BDL	BDL	0.23	3.91	BDL	85.76	0.09	BDL	
BH 4		40.32	BDL	BDL	BDL	0.03	3.64	BDL	78.57	2.64	BDL
BH5	36.68	BDL	BDL	BDL	1.93	5.01	BDL	90.24	BDL	BDL	
BH 6	32.97	BDL	BDL	BDL	0.65	2.72	0.02	93.66	0.26	0.07	

BH7	38.21	BDL	BDL	BDL	0.40	3.32	BDL	101.29	0.14	BDL
BH 8	26.18	BDL	BDL	BDL	0.47	2.96	BDL	45.36	0.04	BDL
BH 9	30.22	BDL	BDL	BDL	0.45	5.30	BDL	19.67	0.11	BDL
BH 10	44.33	BDL	BDL	BDL	0.35	5.92	BDL	37.46	0.38	BDL
BH 11	160.75	BDL	BDL	BDL	0.64	14.39	BDL	51.53	BDL	0.25
R1	38.47	BDL	0.03	BDL	18.4	7.59	0.25	116.65	0.12	BDL
R2	31.45	BDL	BDL	BDL	4.45	8.46	1.27	81.93	BDL	BDL
R3	40.66	BDL	BDL	BDL	4.08	8.01	0.13	70.18	0.33	BDL
R4	39.37	BDL	BDL	BDL	2.11	9.44	0.94	85.51	0.17	BDL
R5	18.99	BDL	0.03	BDL	3.43	5.24	BDL	101.23	0.12	BDL
Min.	18.99	BDL	0.01	BDL	0.03	2.72	0.02	19.67	0.09	0.06
Max.	201.29		0.03		18.40	14.39	1.27	116.65	2.64	0.25
Mean	55.59		0.02		2.009	6.71	0.52	74.35	0.31	0.13
SD	52.08		0.01		3.98	3.15	0.551	25.06	0.59	0.09

SW: Shallow wells, BH: Boreholes, R: River water, below detection limit (BDL)

Table 4: Metal ions concentration in water samples from shallow wells, boreholes and rivers in the upper Athi River catchment in May 2012

Sites	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Na	Pb	Zn
SW1	36.63	BDL	BDL	BDL	0.33	2.91	BDL	64.60	BDL	0.44
SW1	34.63	BDL	BDL		BDL	1.22	7.07	BDL	56.40	BDL 0.38
SW3	185.75	BDL	BDL		BDL	1.57	9.33	BDL	74.25	BDL 0.26
SW4	153.13	BDL	BDL		BDL	0.86	7.90	BDL	39.85	BDL 0.39
SW5	14.75	BDL	BDL		BDL	0.98	3.35	0.075	23.50	BDL 0.54
BH1	26.63	BDL	BDL	BDL	0.76	4.19	BDL	64.85	BDL	0.55
BH2	36.00	BDL	BDL		BDL	1.40	6.46	BDL	83.55	BDL 0.20
BH3	22.13	BDL	BDL	BDL	1.00	2.96	BDL	79.00	BDL	0.20
BH4	33.50	BDL	BDL		BDL	0.92	2.82	BDL	71.30	BDL 0.27
BH5	29.50	BDL	BDL		BDL	7.54	3.93	BDL	84.75	BDL 0.94
BH6	26.88	BDL	BDL		BDL	1.11	2.40	BDL	83.74	BDL 0.17
BH7	29.25	BDL	BDL		BDL	0.55	2.96	BDL	88.60	BDL 0.24
BH8	20.25	BDL	BDL		BDL	0.52	2.84	BDL	36.75	BDL 0.23
BH9	22.63	BDL	BDL	BDL	0.67	4.62	BDL	11.75	BDL	0.46
BH10	36.53	BDL	BDL	BDL	0.73	5.31	BDL	30.45	BDL	0.29
BH11	149.38	BDL	BDL		BDL	0.54	10.96	BDL	43.15	BDL 0.43
R1	32.40	BDL	BDL		BDL	3.63	6.62	0.13	102.20	BDL 0.27
R2	28.25	BDL	BDL		BDL	3.86	7.25	0.90	73.95	BDL 0.25
R3	37.85	BDL	BDL	BDL	0.80	6.77	0.03	64.45	BDL	0.31
R4	32.10	BDL	BDL		BDL	14.13	7.62	0.79	78.15	BDL 1.11
R5	15.55	BDL	BDL	BDL	5.06	4.83	0.18	95.20	BDL	0.31
Min.	14.75	BDL	BDL		BDL	0.33	2.82	0.08	11.75	BDL 0.17
Max.	185.75	BDL	BDL		BDL	14.13	10.96	0.90	102.20	BDL 1.11
Mean	47.79				2.29	5.38	0.35	64.31		0.40
SD	48.951				3.27	2.42	0.386	24.73		0.233

SW: Shallow wells, BH: Boreholes, R: River water, below detection limit (BDL)

IV. Conclusion

Ground water is weakly alkaline due to the presence of carbonates and hydrogen carbonates present in most rock structure in the area studied. The results also indicated that ground water had high electrical conductivity due to the large amounts of total dissolved solids present. It was however noted that ground water had low turbidity since as the water percolates into the underground rocks, the rocks act as filters [43] trapping any solid particles. The colour of underground water was generally low due to the fact that the area under study only had traces of coloured transition elements.

The number of coliforms and *E. coli* was very low in ground water as compared to surface water. Most surface run-offs had high numbers of total coliforms and *E. coli*. From the results, boreholes recorded lower levels of coliforms than shallow wells since most boreholes are well sealed unlike shallow wells where water is

extracted using manual methods of pulley system meaning that the wells are not always protected and are prone to flooding from surface run-off as well as contamination by containers used to draw water from the wells. Results showed that iron levels were the highest in ground water tested followed by zinc and only traces of other heavy metals. The results indicate that the underground rocks have high levels of iron and zinc.

The levels of sodium in ground water were very high and since levels of sodium combines with chlorides the water becomes unpalatable due to its salty taste. The levels of calcium and magnesium were high meaning that the water is hard. Hard water affects the amount of soap used during laundry work due to the scam formed. The levels of fluorides were a major concern. According to WHO drinking water quality guidelines water for domestic use should not exceed 1.5 ppm fluoride levels. In Borehole BH6 located at Athi Primary school had the highest levels of fluoride ions at 9.36 ± 0.04 ppm which was way above the 1.5 ppm limit set by WHO for drinking water. Children in this study area had brown teeth and with continued use of the only source of water available they may develop diseases such as osteomalacia later in their lives. Results showed that levels of nitrates in ground water were generally low.

Borehole BH4 at Brookshine School had the highest levels of lead at 2.64 ± 0.04 ppm while sodium and iron levels were highest in river water sample R1 situated at Mbagathi River at Mombasa Road Bridge with levels of 116.65 ± 0.02 ppm and 18.40 ± 0.35 ppm respectively. Sampling site SW3 located at Ngund'u had the highest levels of calcium, magnesium and chloride. The analysis showed 201.29 ± 0.04 ppm calcium ions, 11.563 ± 0.02 ppm of magnesium ions and 226.49 ± 0.04 ppm of chloride ions. Levels of carbonates and bicarbonates ions were highest in borehole sample BH5 located at Athi Primary School whose levels were $64.117 \pm$ ppm. High levels of sulphates were found river sample R5 located at Brookshine Bridge near Brookshine School while river sample R4 located at Ongata Rongai Bridge had the highest level of nitrates at 15.68 ± 0.01 ppm. *E coli* and faecal coliforms were highest in river water sample located at Mombasa road Dam wall 309 ± 3.41 MPN.

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