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Research Article

Evaluation of Ground Water and Tap Water Quality in the Villages Surrounding Chuka Town, Kenya

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Abstract: This study was carried out to assess the groundwater and tap water quality of the villages around Chuka Town. The physicochemical and microbiological parameters were examined during wet and dry season. The results showed that pH, turbidity, fluoride, phosphorous, Fe, Mn, Pb, MPN of coliform organisms were above recommended levels by WHO, while the levels of the other parameters investigated were within the required levels by WHO. This reveals that people using these water sources are at a potential risk of contracting diseases. Hence a strong prevention measures are required to save the ground water and tap water from contamination.

Key Words: Ground water quality, microbiological quality, physicochemical quality. drinking water, season, water quality.

INTRODUCTION

Water is a chief natural resource, essential for the existence of life and is a basic human entity [1-5] .It is the fundamental right to get pollution free water to every individual but because of development pollution of water sources are unavoidable[6-10].The degradation of both surface and ground water resources contributes to adverse impact on the quality of drinking water for human use, as well as harmful effects on aquatic life [11-14].The failure of the government to provide safe water for domestic use has contributed to the people living around Chuka town to solely depend on well, spring and irrigation water.

During passage through the ground, water dissolves minerals in rocks, collect suspended particulate matter particularly those of organic sources as well as pathogenic micro-organisms from faecal matter[15-17]

Certain minerals are toxic such as the heavy metals. Although some of the heavy metals act as micro-nutrients at lower concentrations, but become toxic at higher concentrations [18-19]. No studies have, however, been done on the water quality with regard to its physical, chemical and microbial activity.

The aim of this study was to determine the physicochemical and microbiological quality of ground water and tap water from villages around Chuka town and to evaluate their suitability for drinking purposes, in accordance to the WHO standards for drinking water.

MATERIALS AND METHODS

Study Area: The area under investigation is located on 0°19’59’’ south latitude and 37°38’45’’ east longitudes in the south of Meru town and is situated at 1445 m above sea level. The area is on the eastern slopes of Mount Kenya and is a rural agricultural area of the Meru speaking Kenyans of Tharaka-Nithi County. The soils are deep, well drained with moderate to high inherent fertility [20].

Sample collection: Composite water samples were collected from ground water and tap water sources during wet and dry season. Two sets of samples, each of 500 ml, were collected from each source; one set of physicochemical analysis and the other set for microbial analysis.

Each sample was collected in either high density polyethylene bottles(physicochemical analysis) or sterilized glass bottles(microbial analysis) with the cap securely tightened .Standard procedures for collection , handling and preservation [21-23] were followed to ensure data quality and consistency. The sampling points are shown in **Table 1.**

Table 1: Sampling Sites

Site No.	SITES	SOURCE
1	Nkubo	Spring
2	kathituni	Spring
3	Gicuca	Shallow well
4	Chera	Borehole
5	Kithembeni	Tap

Chemical Analysis: The following physicochemical parameters were determined in situ at the time of sample collection, pH, temperature, conductivity and turbidity **(Table 2).**Other water quality parameters was analyzed in the laboratory using standard procedures [21,24]. Atomic absorption spectrometry (Varian spect-AA-10 model)was employed for the determination of trace metals in water samples. The standard reference materials from the National Institute of Standards and Technology, USA were used for the validation of the atomic absorption spectrophotometric method. The specific methods employed under this investigation have been summarized in **Table 2**.

Table- 2: Water quality test methods

Parameters	Test Methods
Temperature	Thermometric
pH	Potentiometric
Electrical conductivity	Conductometric
Turbidity	Nephelometric
Total dissolved solids	Gravimetric
Total suspended solids	Gravimetric
Total alkalinity	Titrimetric
Total acidity	Titrimetric
Total hardness	EDTA titrimetric
Sulphate	Turbidimetric
Ammonia	Nessierization spectrophotometric
Nitrate	Ultraviolet spectrophotometric
Nitrite	spectrophotometric
chloride	Argentometric
Fluoride	Ion-selective electrode
Phosphorous	Spcetrophotometric
Metals	Atomic absorption spectrophotometric
MPN of coliforms organisms/100 mL	IDEXX Quanti-Tray/2000
E. coli/100 mL	IDEXX Quanti-Tray/2000

RESULTS AND DISCUSSION

Physicochemical quality: The overall mean results of the physicochemical parameters of ground water and tap water sources in the study area are shown in Table 3.The results of the parameters which were not within the limit prescribed by WHO are also analyzed graphically as shown in **Figure 1-4.**

Mean temperature ranged from 20 to 22°C in wet season and 20.31 to 22°C in dry season. The minima and maxima was obtained from site 4 and 3 respectively during wet and dry season .A temperature change of 0.31°C due to seasonal variation was observed at site 4,while at site 3, a temperature variation of 1.70 °C was recorded. This result indicates that, temperature changes due to changes in climatic conditions do not play a significant role in deeper ground water composition but it does for shallow ground water. The seasonal variation of shallow ground water, which was observed, could be attributed to warming or cooling at the surface or introduction of water from the surface during high recharge time periods. When shallow ground water is compared to tap water, the tap water showed a minor variation and this might be due to solar radiation and the atmospheric spatial and temporal changes in tap water. The differences in temperature variation due to seasonal changes at site 1 and 2 could be attributed to the soil type within the area. The rise in temperature of water accelerates chemical reactions, reduces solubility of gases, amplifies taste and odour, elevates metabolic activity of organisms and increases TDS.

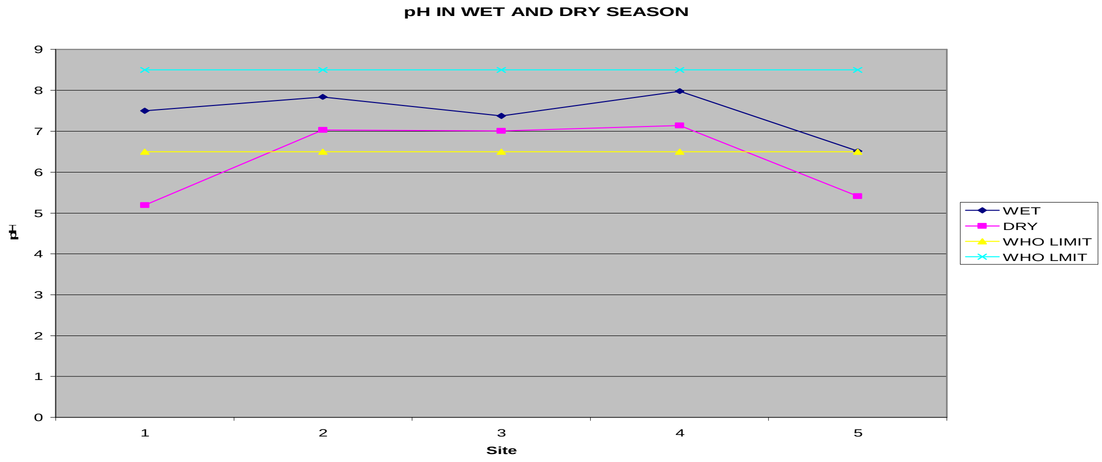

Figure 1:pH level in wet and dry season

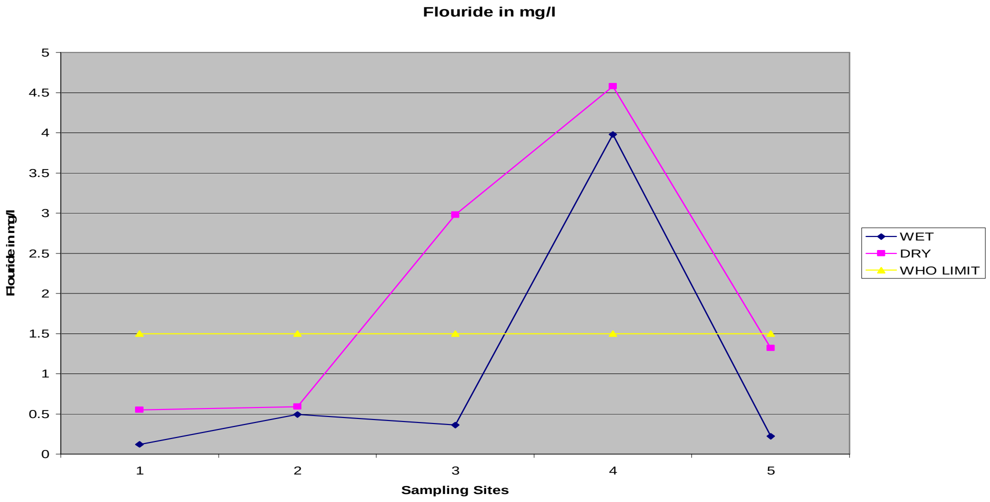

Figure 2: Turbidity levels in wet and dry season

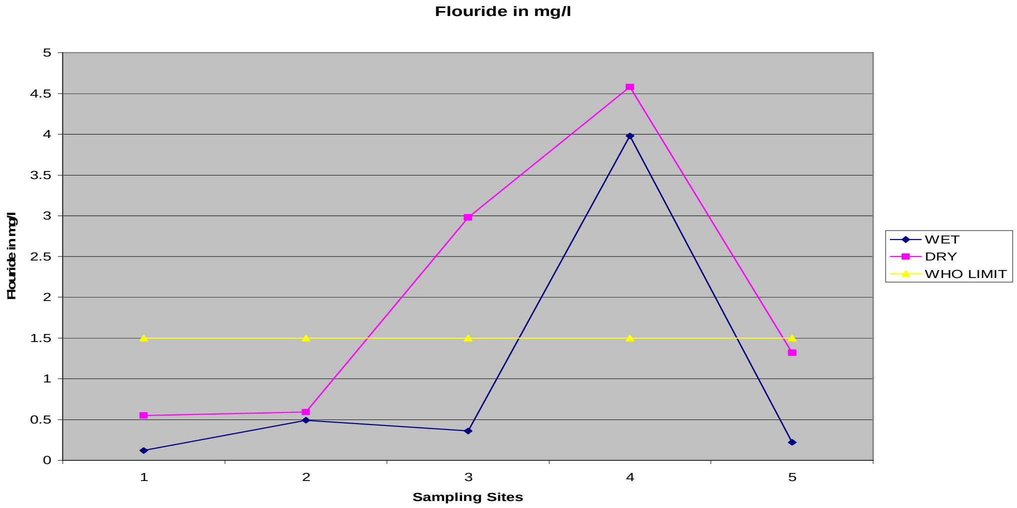

Figure 3: Flouride levels in wet and dry season

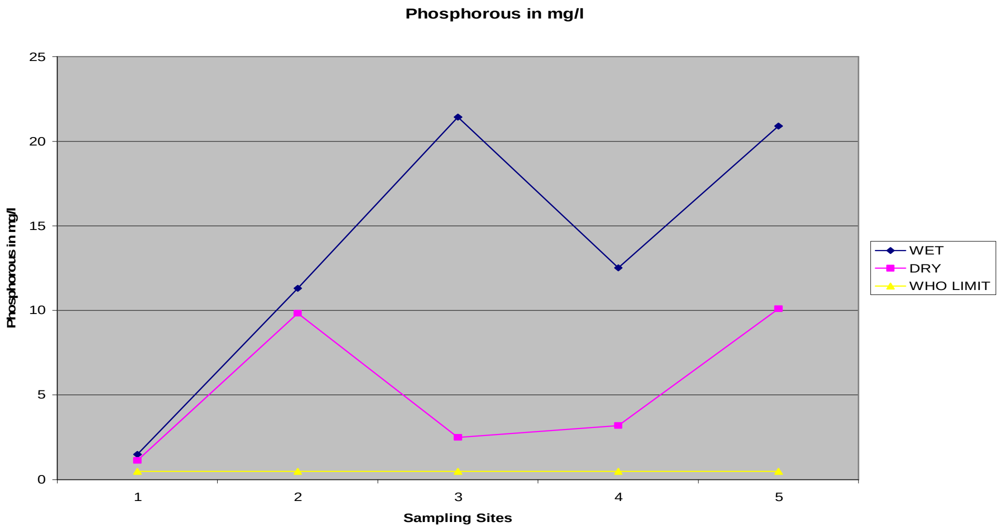

Figure 4: Phosphorous levels in wet and dry season

The pH is a measure of the hydrogen ion (H^+) availability (activity).Mean pH ranged from 6.51 to 7.98 during the wet season. Site 5 had the least value of pH of 6.51 while site 4 had the highest value of 7.98.During the dry season, the mean pH ranged between 5.19 to 7.14.The minima and maxima was observed at site 1 and 4 respectively. Higher pH values during wet season could be due to waste discharge, microbial decomposition of organic matter in the water body.

The acidic pH of water at site 1 and 5 could be due to dissolved carbon dioxide and organic acids such as fulvic and humic acids, which are derived from the decayed and subsequent leaching of plant materials .In addition great reduction in water volume, could decrease pH. In the present study site 1 and 5 during dry season were not within acceptable range of 6.5-8.5.The low pH at sit 1 and 5 might cause redness and irritation of eyes in human beings and also can affect the extent of corrosion of metals as well as disinfection efficiency of distributing systems.

Electrical conductivity signifies the amount of total dissolved salts. It is a tool to assess the purity of water. The electrical conductivity values in the study area were found in the range of 0.03 to 10.68 µmho/cm in wet season, with the lowest being observed in site 1 and the highest in site 4.High electrical values at site 4 indicates the presence of high amount of dissolved inorganic substances in ionized form. The values of electrical conductivity depend upon temperature, concentration and types of ions present. The average values of electrical conductivity during dry season ranged between 0.85 to 14.13 µmho/cm. The minima and maxima were observed at site 2 and 4 respectively. This was attributed to the effect of the pH and the concentration of ions present in each site. The low pH at site 4 in comparison to site 2 indicates high hydrogen ion concentration. The hydrogen ion is very small and is able to enter and disrupt mineral structures so that, they contribute to dissolved constituents. Consequently, the greater the H^+ availability, the higher the TDS in the water. The values were found to be within the recommended range for WHO for both seasons. The electrical conductivity can be classified as type 1, if the enrichment of salts are low(EC<1,500 µmho/cm),type II, if the enrichment of salts are medium (EC=1,500 to 3000 µmho/cm) and type III if the enrichment of salts are high (EC>3000 µmho/cm).According to the above classification of EC, the ground water and tap water samples come under type I.

According to WHO specification TDS up to 500 mg/l is the highest desirable and up to 1,500 mg/l is maximum permissible. In the study area the mean TDS value varies between 0.02 to 10.23 mg/l in wet season and 0.35 to 8.46 mg/l in dry season. The results indicates that ground water and tap water samples from the study area lies within the minimum permissible limit .High levels of TDS in the water samples during the dry season could be due to leaching of salts from soil and also a decrease in the volume of water. The values of TSS and total solids were found be within the recommended levels of WHO.

Mean turbidity values during the wet season ranged between 0 to 7.19 NTU, while that of the dry season ranged between 0 to 2.81 NTU. The lowest value was observed in spring water and deeper ground water samples in both seasons. While the highest value was observed in open shallow groundwater in wet season. The high value observed during wet season could be attributed to a high rate of impurities flowing into the open shallow groundwater. The turbidity levels at site 3 and 5 during wet season were found to be higher than the recommended values of WHO and hence not suitable for domestic purposes. Turbidity can provide shelter for opportunistic microorganisms and pathogens.

Alkalinity in natural water is due to the presence of salts of weak acids. Natural waters contain appreciable amounts of carbonate and hydroxalalkalinites. The mean alkalinity values in the present investigation ranged from 0.40 to 7.68 in wet season and 0.19 to 5.33 in dry season. These results indicate that, the levels of alkalinity are high in wet season than in dry season. This could be attributed to alkaline substances which are able to reach water body during this period. The minima and maxima was observed at site 3 and 4 respectively. The values observed in the present investigation were within the WHO allowable limit for drinking water.

In the present study the mean total hardness was in the range of 2.0 -23.32 mg/l and 0.2 -17.81 mg/l in wet and dry season respectively. High concentration during wet season might be due to the solvent action of rain water coming in contact with soil and rocks which is capable of dissolving calcium and magnesium. The minima and maxima was observed at site 3 and 4 respectively during wet and dry seasons. In the present study no sample exceeded the maximum limit set by WHO.

Values of calcium in the water samples ranged from 0.41 to 29.11 mg/l and 0.38 to 26.13 mg/l in wet and dry season respectively. For magnesium in water samples the values ranged from 0.20 to 5.89 mg/l and 0.14 to 4.88 mg/l in wet and dry season respectively. These values were below the maximum guidelines given by WHO. These comparatively low values for these cations definitely contributed to the low values measured for total hardness in the water samples.

Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals. Discharge of industrial wastes and domestic sewage tends to increase its concentration. High concentrations of sulphate in drinking water may cause transitory diarrhea and also it may interfere with uptake of other nutrients. The upper limit of sulphate concentration as given by WHO for drinking water is 250 mg/l. The sulphate levels in the study area ranged between 0 to 13.32 mg/l and 0 to 9.93 mg/l in wet and dry season, indicating that all samples fall within the desirable limit. Minima and maxima was observed at site 5 and 2 respectively during wet season ,while during dry season minima and maximum occurs at site 5 and 3 respectively. High levels of sulphate at site 2 during wet season and site 3 during dry season might be due to leaching from gypsum and other common minerals.

The high concentration of nitrates in drinking water causes methenoglobinemia in infants, a disease characterized by blood changes .Main sources of nitrate contamination are human and animal wastes ,industrial effluents, application of fertilizers and chemicals, seepage and silage through drainage system. Mean nitrate concentration ranged from 1.71 to 21.33 mg/l and 1.23 to 6.79 mg/l in wet and dry season. The highest concentration during wet season might be due to application of nitrogenous fertilizers to agricultural land. Minima and maxima were observed at site 5 and 3 respectively. High levels at site 3 might have originated from decaying organic matter, discharge of sewage and inorganic fertilizers. The observed values were within WHO guidelines for nitrates in drinking water. Levels of nitrites and ammonia were also analyzed and were found to be within the recommended values set by WHO.

The levels of chloride in water body may be from diverse sources such as weathering, leaching of sedimentary rocks and soils, intrusion of salt water, windblown salt in precipitation, domestic and industrial waste discharges, municipal effluents. The mean chloride concentration in the present study varied from 6.00 to 20.99 and 11.00 to 34.95 mg/l in wet and dry season. High levels observed during dry season might be due to decrease in water volume and also might have been caused by domestic waste discharge. Minima and maxima was observed at site 5 and 4 respectively in both seasons. High concentrations at site 4 could be attributed to weathering, leaching of sedimentary rocks and soils. The chloride content values of all samples analyzed were found to be within the limit (250mg/l) recommended by WHO. People accustomed to higher chloride in water are subjected to laxative effects.

Fluoride ions have dual significance in water supplies. High concentration of fluoride ion cause dental fluorosis(Disfigurement of teeth).At the same time a concentration less than 0.8 mg/l results in dental carries. Hence it is essential to maintain the fluoride ion concentration between 0.8 to 1.0 mg/l in drinking water. Mean concentration of fluoride ions varied from 0.12 to 3.98 mg/l and 0.55 to 4.58 mg/l in wet and dry season respectively. Minimum fluoride concentration observed during wet might be due to the availability of large volume of water leading to dilution of chemicals present. High concentration during dry season could be due to depletion of water leading to the concentration effect. The concentration levels of fluoride ions at site 3 and 4 in both seasons were above the limit set by WHO for fluoride in drinking water (1.5mg/l).This could be attributed to weathering and leaching of bedrock with a high fluoride content.

Phosphorous may occur in water as result of domestic sewage, detergents, agricultural effluents with fertilizers and industrial waste water. High concentration of phosphorous, therefore, is indicative of pollution. Mean concentration of phosphorous ranged between 1.50 to 21.42 mg/l and 1.12 to 10.10 mg/l in wet and dry season respectively. High concentration of phosphorous during wet season might be due to agricultural effluents with fertilizers. The lowest concentration was observed at site 1 during dry and wet seasons, while the highest concentration of phosphorous was observed at site 5 and 3 in dry and wet season respectively. High values at site 3 during wet season could be attributed to domestic sewage and detergents. The levels of phosphorous in ground water studied were above recommended limit (0.5 mg/l) by WHO. This implies that water from these sources is not suitable for drinking purposes.

Levels of trace metals in water samples: The concentration of trace metal in the water samples are shown in table 4.The concentration of the trace metals which were not within the limit prescribed by WHO are also analyzed graphically as shown in **Figure 5 to 7.**In the present study, the mean concentration of the Sb, Cd, Mo, V, Sr in the water samples were below their respectively detection limits for the analytical method used. The mean values for Na, Ca, Mg, Zn, Cu, Cr, B and Al at all the sampling sites were below the WHO maximum guidelines values for the respective elements in drinking water. The concentration of Fe, Mn and Pb in some sampling sites were above the recommended limit by WHO.

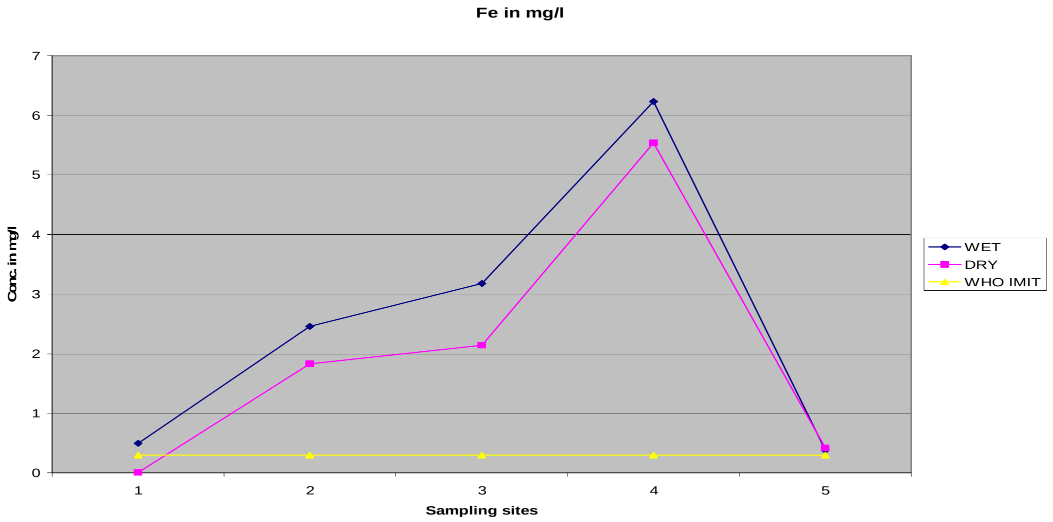

Figure 5: Fe levels in wet and dry season

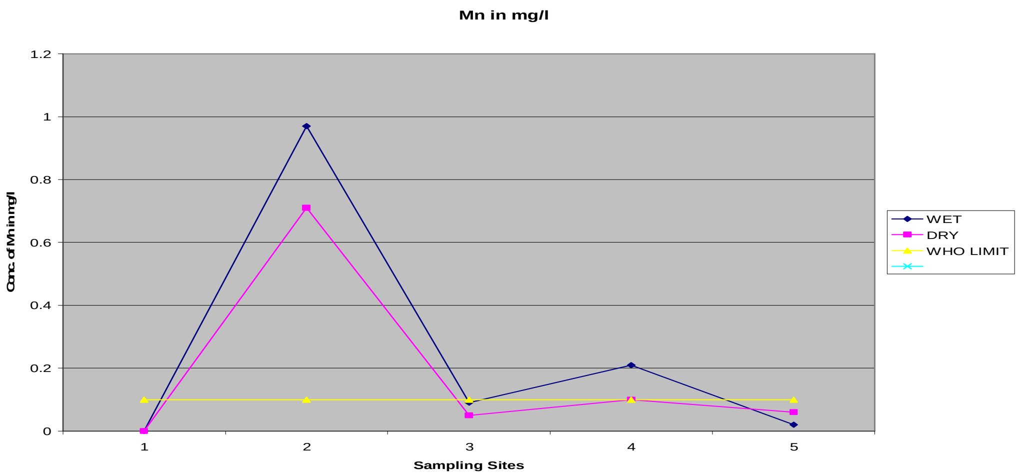

Figure 6: Mn levels in wet and dry season

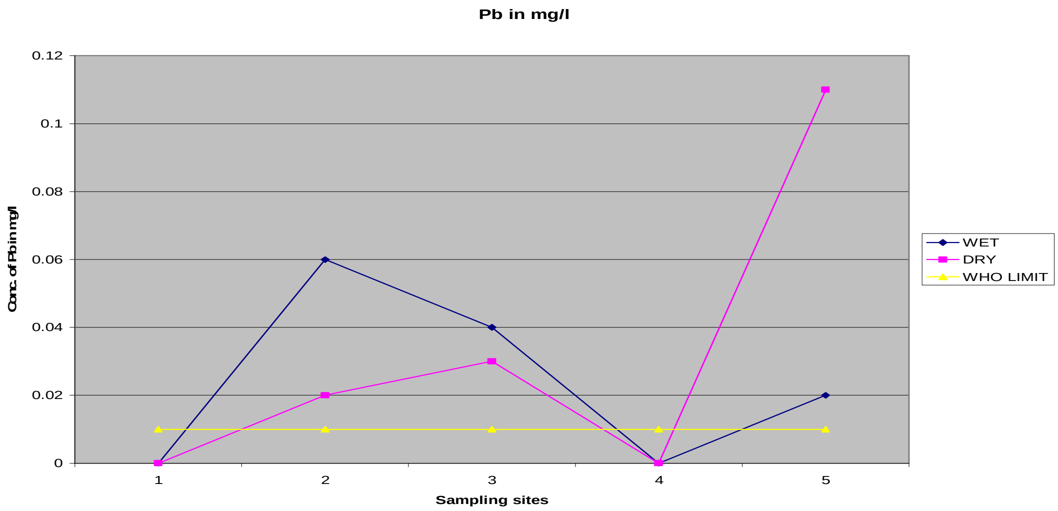

Figure 7: Pb levels in wet and dry season

Table- 3. Physicochemical characteristics of groundwater and tap water in the study area

	Site 1		Site 2		Site 3		Site 4		Site 5		WHO (2011)
seasons / Parameters	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	
Temperature(^{o}C)	21.30	22.00	20.81	21.78	22.00	23.70	20.00	20.31	21.00	21.52	NS
pH	7.28	5.19	7.84	7.03	7.38	7.01	7.98	7.14	6.51	6.41	6.5-7.5
Electrical Conductivity(μΩ/cm)	0.03	6.45	0.65	0.85	0.34	1.45	10.68	14.13	6.49	6.39	1500
Total Dissolved solids(mg/L)	0.02	4.31	0.40	0.35	0.32	1.25	10.23	8.46	5.04	3.87	600-1000
Total Suspended solids(mgL)	4.00	0.12	0.11	0.04	0.07	0.02	4.77	0.08	7.81	0.12	500
Total Solids(mg/L)	8.31	0.14	0.51	0.39	1.32	0.34	13.23	10.31	11.68	5.16	500
Turbidity(NTU)	ND	ND	ND	ND	7.19	2.81	ND	ND	5.37	1.00	5
Total alkalinity(mg/L)	4.00	2.00	4.66	4.03	0.40	0.19	7.68	5.33	3.79	2.03	120-600
Total acidity(mg/L)	0.16	2.20	0.20	0.65	2.41	0.03	2.72	0.37	2.00	0.21	NS
Total hardness(mg/L)	10.00	4.00	17.67	0.25	2.00	0.20	23.32	17.81	6.77	2.55	100-500
Sulphate(mg/L)	0.27	4.82	13.32	2.07	3.99	9.93	2.10	4.50	ND	ND	250
Ammonia(mg/L)	0.47	0.41	0.13	1.30	1.18	0.27	0.23	0.40	0.39	0.14	35
Nitrates(mg/L)	3.38	2.94	5.21	1.30	21.33	6.79	10.34	6.12	1.71	1.23	50
Nitrite(mg/L)	0.18	0.35	0.08	2.76	0.12	0.24	0.02	0.25	0.73	0.51	3
Chloride(mg/L)	12.96	11.00	10.11	20.99	7.00	15.00	20.99	34.95	6.00	10.87	250
Fluoride(mg/L)	0.12	0.55	0.49	0.59	0.36	2.98	3.98	4.58	0.22	1.32	1.5
Phosphorous(mg/L)	1.50	1.12	11.30	9.83	21.42	2.49	12.52	3.18	20.90	10.10	NS

KEY: ND-Not detected; NS-Not Specified

TABLE 4: Levels of trace metals in groundwater and tap water in the study area

Season parameters (mg/l)	SITE 1		SITE 2		SITE 3		SITE 4		SITE 5		
	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WHO (2011)
Na	3.50	3.45	7.39	6.10	28.50	18.15	32.10	29.10	1.27	2.10	200
Ca	0.41	0.39	8.35	5.89	25.81	2.90	29.11	26.13	0.38	0.43	75
Mg	0.20	0.16	0.90	0.51	4.78	1.20	5.89	4.88	0.14	0.27	30
Fe	0.50	0.01	2.46	1.83	3.18	2.14	6.23	5.54	0.38	0.42	0.3
Mn	ND	ND	0.97	0.71	0.09	0.05	0.21	0.10	0.02	0.06	0.1
Zn	0.15	ND	0.26	0.18	0.23	0.04	0.24	0.15	ND	ND	5.0
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0
K	1.70	ND	ND	ND	1.87	1.65	4.81	2.10	0.89	0.98	NS
Cr	0.01	ND	ND	ND	0.05	0.03	ND	ND	0.02	0.03	0.05
Pb	ND	ND	0.06	0.02	0.04	0.03	ND	ND	0.02	0.11	0.01
Sb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.02
Co	0.14	ND	ND	ND	0.24	0.01	ND	ND	ND	ND	NS
Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.03
Mo	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
B	ND	ND	ND	ND	ND	ND	ND	ND	1.97	2.02	2.4
V	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
Si	17.23	11.11	9.99	8.77	23.01	22.65	32.74	31.23	3.98	4.89	NS
Sr	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
Al	ND	ND	0.03	0.02	ND	ND	ND	ND	ND	ND	NS

KEY: NS: Not Specified; ND: Not Detected

Iron is undesirable component in drinking water. Toxic effects due to exposure to iron leads to abdominal discomfort, lethargy and fatigue. Liver is the major site for iron storage .Excess iron deposition leads to shrinkage of liver followed by fibrosis and cirrhosis .Ingestion accounts for most of the toxic effect of iron because iron is absorbed rapidly in gastrointestinal tract. Major sources of pollution are mining, acid mine drainage, corroded metal, domestic and industrial waste. In the present study the mean concentration of iron in water samples ranged from 0.38-6.23 mg/l and 0.01 to 5.54 mg/l in wet and dry season respectively.

The results reveals that, iron concentration in ground water was high during wet season and this might be due to influence of rainfall infiltrating and dissolving iron minerals in rock and soil which are leached into ground water sources. The highest mean concentration for tap water was observed during dry season and this can be attributed to reduction in water volume. The lowest iron concentration was observed at site 5 and 1 in wet and dry season respectively while site 4 recorded highest concentration in both season. High concentration at site 4 might be due to the weathering of the rocks underlying the basin.90% of water samples analyzed had iron levels above recommended limit by WHO.

Manganese at low concentrations contributes to the well being of the cells of humans, because it acts as a co-factor in some enzymatic reactions such as those involved in phosphorylation, synthesis of fatty acids and cholesterol. However, when exposed to higher levels of Mn, it gets accumulated in kidney, liver and bones and cause “manganese psychosis”, which is an irreversibly brain disease characterized by uncontrorable laughter, euphoria, impulsiveness, sexual excitement followed by impotency .

The industrial processes are the major sources of manganese pollution. Most of the manganese in the environment is due to burning of fossil fuels. Use of manganese bearing fertilizers also contributes to air and water pollution by Mn. In the present investigation, the concentration of manganese ranged from 0 to 0.97 mg/l and 0 to 0.71 mg/l in wet and dry season. The levels of Mn are higher in the wet season when compared to that of the dry season. The results obtained indicates that 20% of the sites had manganese levels above WHO allowable range for drinking water in the wet season while only 10% of the sites were above during the dry season.

Lead interferes with heme synthesis and leading to hematological damage. Pb inhibits several important enzymes involved in the overall process of heme synthesis. Lead finds entry into the water through the discharge of waste waters emanating from printing, dyeing industries and oil refineries. The mean concentration of lead ranged from 0 to 0.06 mg/l and 0 to 0.03 mg/l in wet and dry season respectively. The highest values were observed during wet season. The study revealed that 30% of the sites had lead concentration above the WHO prescribed limit for drinking water in both seasons. The high levels might be due to the use of chemical fertilizers.

Microbial water quality: Outbreaks of disease, often of epidemic proportions can occur if human wastes that are infected with pathogens enter water supplies. Diseases that are transmitted when people drink contaminated water, swim in it, and include cholera, typhoid fever, dysentery, infections, hepatitis and polio. Because it would be practically impossible to test for each of the wide variety of pathogens that may be present, microbiological water quality monitoring is primarily based on tests for indicator organisms.

The coliform bacteria count is used to test water for contamination by microorganisms. Coliform bacteria (*Escherichia coli*) live naturally in the human intestinal tract and the average person excretes billions of them in feaces each day. The term “coliform bacteria” refers to a vaguely defined group of gram negative bacteria that have a long history in water quality assessment. Coliform bacteria are harmless and cause no diseases, but their presence in water is an indication of fecal contamination. If none are found, the water is free from fecal contamination and can be assumed to be free from pathogenic organisms.

In the present study the mean MPN of coliform organisms/100 ml were found to be greater than 2420 during wet season while during dry season it ranged from 816 to >2420.The lowest number during dry season was observed at site 1 and the highest was observed at site 3 and 5.The mean of E.coli/100 ml ranged from 107.2 to 2420 and 4 to 88.2 in wet and dry season respectively.

There was a highly significant variation in *E.coli* between wet and dry season. The high number of MPN of coliform organisms /100 ml and *E.coli*/100 ml during wet season might be due to the entrance of animal and human wastes into the water bodies. The minimum number of *E.coli*/100 ml was observed at site 4 and 1 in wet and dry season respectively, while the maximum number was observed at site 1 and 2 in wet and dry season. These results showed major contamination from biological effects with the number exceeds recommended limit for human consumption.

TABLE 5: LEVEL OF BACTERIOLOGICAL PARAMETERS

Sampling Sites	WET SEASON		DRY SEASON	
	Total Coliform Bacteria/100	E.Coli/100ml	Total Coliform Bacteria/100	E.Coli/100ml
1	>2420	>242O	816	4
2	>2420	960.6	1733	88
3	>2420	144	>2420	55
4	>2420	107.2	>830	44
5	>2420	178	>2420	64

CONCLUSIONS

Physicochemical and microbiological parameters of water samples from ground water and tap water from villages around Chuka town were examined. The results obtained revealed that the concentration of pH, turbidity, fluoride, phosphorous, Fe, Mn, Pb, MPN of coliform organisms/100 ml and *E.coli*/100 ml were above recommended levels by WHO while the levels of the other parameters investigated were within the required levels by WHO. In conclusion, it is necessary to disinfect ground water and tap water before human use in order to avoid the potential risk of contracting diseases. The physicochemical ad microbiological quality that adversely affected the quality of ground water and tap water is likely to arise from a variety of sources. Hence it is important to apply strong prevention measures to save ground water and tap water from contamination.

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