Assessment of Selected Physico-Chemical Parameters of Groundwater in Chuka Igambang'Ombe Constituency, Kenya

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Abstract

Groundwater is an essential source of water for drinking and other domestic uses. Recently, there has been high dependence on groundwater due to water shortage as a result of changing climates, and higher costs of accessing piped water. An occurrence of the physico-chemical parameters of the groundwater in levels past the WHO highest permissible limits can cause serious health implications to the consumers of the groundwater. This study therefore, assessed the extent of the physico-chemical parameters concentration of the groundwater in Chuka, Igambang'ombe constituency. A total of five samples was collected from 5 boreholes in the Mucw'a and Ndagani regions surrounding the Chuka University main campus. Selected physical parameters were recorded onsite by use of portable apparatus. Samples for testing chemical parameters were collected and transported in cooler boxes to Chuka University laboratories for analysis. Physical parameters determined onsite were dissolved oxygen (DO), temperature, and the pH. Dissolved Oxygen meter, mercury thermometer, and pH meter were the equipment used to test the respective physical parameters. UV- spectrophotometry was used to analyze the chemical parameters: nitrates, and phosphates, where absorbance was recorded at a wavelength of 220-820 nm and 880nm respectively. The assessment was conducted during the relatively dry months of January to March. The temperature of the water ranged from 22.8-25.2^{0}C. The pH levels ranged from 4.50 – 9.50. The high altitude nitrate levels were 2.4mg/L, and 7.37mg/L at the low altitude. The phosphate concentrations were below detectable limits. The results were then compared with WHO standards for the highest permissible levels for the tested parameters to determine the suitability of the water for consumption. All the tested parameters lied within the WHO permissible limits for drinking water except for the pH levels.

Keywords*:* *Groundwater, physical parameters, chemical parameters, infiltration, suitability,*

INTRODUCTION

Groundwater is ideally the most essential component of the water cycle as it's a key source of potable water, especially in Africa. It contributes to up to two thirds of the world's freshwater resources. Groundwater is highly relied on due to the uneven distribution and inaccessibility of surface water resources of the world (Chapman, 1996 and BGS, 2011).

According to Onwughara (2013), drinking water should be of high quality as presence of physical and chemical elements past the permissible standard levels make the water unsuitable for consumption. Groundwater faces a great threat to its quality due to contamination. Thus, it is hard to access clean, safe and potable water in most African developing countries such as Kenya (Dara and Mishra, 2011; Idibie et al., 2018).

Prospects by the Water Resource Authority ([WRA], 2018), depict potential worsening of the shortage of potable water by the year 2030. This will be due to human activities that influence groundwater quality such as wastes carried into boreholes by means of flash floods, leaching of septic and buried wastes etc. According to Talafre and Knabe (2009), it is estimated that droughts and other forms of water scarcity will affect up to one third of the world's population, and will influence consumption and migration patterns.

Even with the associated health concerns (Palamuleni and Akothi [2015], Idibie et al., 2018), noted that up to 1.5 billion world population depend on untreated groundwater. According to WHO (2011), the highest permissible levels for nitrates is 10mg/L. Consumption of water whose nitrates concentration surpasses the WHO standards cause bluebaby syndrome ormethaemoglobinaemia for young children (Jain and Agarwal, 2012). It is also known to cause cancer to humans (Ayesha et al., 2012; WHO, 2011). Although there are no set standards for phosphate levels in drinking water, clean water usually has low levels of phosphates (Ombaka et al., 2013).

An assessment of groundwater is therefore, essential in order to determine the suitability of the water for consumption. The data obtained can be utilized to manage health implications resulting from water contamination. This study was thus conducted to establish the extent of selected physico-chemical parameters borehole water in Chuka, Igambang'ombe constituency.

METHODOLOGY

Study Area

Chuka is in Tharaka Nithi county, eastern part of Kenya and it lies below the slopes of Mt. Kenya. Tharaka Nithi county is situated between longitudes 37^0 19' East and latitudes 000 07' and 000 26' south. Chuka area is a section of Igambang'ombe constituency and has an area coverage of 624.4 km^2. The county receives an average annual rainfall of 717 mm. Chuka being part of the high altitude areas receives a reliable rainfall while the low altitude regions such as Kathwana receive low and poorly distributed rainfall. The temperatures in the county range from as low as 14^0C to 30^0C in highland areas and 22^0 C to 36^0C in the low altitude region. Chuka and Chogoria towns have exhibited a fast growth with an increase in population (GOK, 2013; KNBS, 2019).

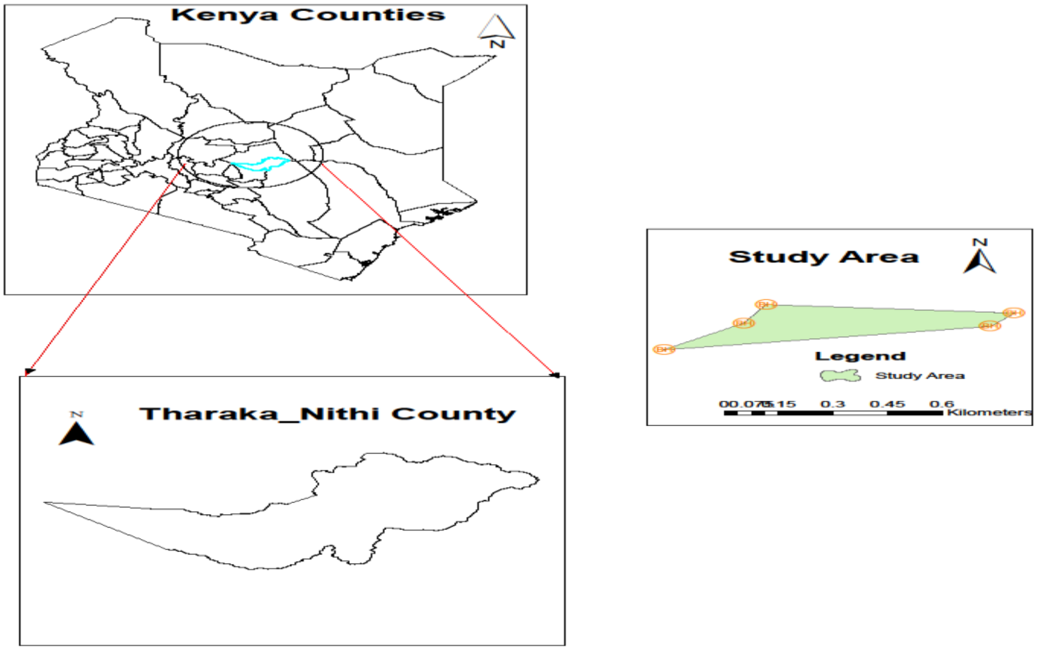

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Figure 1: A map showing the specific study area that the boreholes were sampled.

Field sample collection and laboratory procedures

Water sample collection

A total of five samples were collected from five boreholes situated in the Ndagani and Muc'wa areas. The samples were collected during the evening hours to avoid interference of the water quality by external factors. They were collected during the relatively dry months of January to March. The boreholes were randomly selected to ensure a true representation of the study area. Before extraction of the samples from the boreholes, 3 buckets full of water were drawn from each borehole to ensure the tested water would represent a true state of groundwater quality. One litre plastic bottles pre-sterilized with 70% ethanol were used to draw the samples. Once filled with water, the bottles aseptically closed, labelled, packed in cool boxes and transported to Chuka University laboratories for analysis.

Physical parameters analysis

The physical parameters dissolved oxygen (DO), temperature and pH were determined on site by use of dissolved oxygen meter, mercury thermometer and pH meter respectively. The results were recorded in triplicates to ensure reproducibility.

Nitrate analysis procedure

Each of the samples were filtered and in each 50mls measured into separate conical flasks. 1 ml of dilute hydrochloric was added to each of the sample containing conical flasks.

Blank solution preparation

This was prepared by measuring 50mls of distilled water and adding 1ml of dilute hydrochloric acid into it.

Standard solutions were prepared following the below procedure

From 100ppm of nitrate; 4 ML to represent 8ppm and 3mls to represent 6ppm were transferred each into a 50mls volumetric flask and filled to mark with distilled water.

Absorbance of the standards, the blank, and the sample solutions was recorded at a standard wavelength of 220- 820nm. The concentrations were then established from the absorbance.

Phosphate analysis procedure

Reagents

Potassium antimonyl tartrate solution

Ammonium molybdate

Dilute sulphuric acid

Procedure for preparation of a combined reagent

To a 150ml conical flask; 50 ML of dilute sulphuric acid were added, 5 ML of potassium antimonyl tartrate solution, 15 ML of ammonium molybdate solution and 30 ML of ascorbic acid stepwise with gentle stirring after every addition.

Full procedure

Each of the water samples were filtered using a Whitman filter paper to remove suspended particles.

25mls of the blank solution, 25mls of each samples, and 25mls of the standard solutions were pipetted into 150mls conical flask each.

4mls of the combined reagent were added into each of the conical flasks and mixed thoroughly for 10minutes.

The absorbance of each was measured within 15-30 minutes at a wavelength of 880nm by use of UV-spectrophotometer. The concentration were established using respective absorbance.

RESULTS AND DISCUSSION

The Physical Parameters

Temperature

The groundwater temperatures ranged from 22.8- 25.2 ^{0} C within all the boreholes. Water from some of the boreholes had temperatures significantly higher compared to others. The temperature data was collected during the morning and evening hours to avoid influence from external factors. This is according to Trivedi (2010), who observed that variations in water temperature could be influenced by the time of sample collection. High temperatures can intensify chemical reactions in an aquifer such as weathering of rocks which can release chemicals to the water thus changing its quality (Murhekar, 2011). The average temperature of the water in both high and low altitude regions did not lie within WHO (2008) highest permissible levels, that is, 28-32.

Table 1: temperature levels of the selected boreholes

Borehole	Temperature	t-Test: Paired Two Sample for Means			
Mc01	25.2				
Mc02	24.6		*temperature*	*WHO standard*	
Mc03	23.6	Mean	23.92	30	
ND01	23.4	Variance	0.932	0	
NDO2	22.8	Observations	5	5	
		Pearson Correlation	#DIV/0!		
		Hypothesized Mean Difference	0		
		df	4		
		t Stat	-14.0825		
		P(T<=t) one-tail	7.38E-05		
		t Critical one-tail	2.131847		
		P(T<=t) two-tail	0.000148		
		t Critical two-tail	2.776445		

pH

The pH of the boreholes water ranged from 4.50 to 9.50. Some of the boreholes exhibited slightly acidic conditions while others exhibited basic characteristics. The weak acidic pH of some of the borehole water could be as a result of dissolved carbon dioxide and organic acids caused by decayed matter which may leach and reach the groundwater. Acidic water can cause redness and irritation of eyes in humans. It can also cause corrosion of pipes in water distribution systems (Ombaka et al., 2013). There is a link between low water pH and gastrointestinal disorders such as hyperacidity and ulcers. Water of higher pH has adverse effects such as scale formation in water heating systems (Buridi & Gedala, 2014). The pH of the water tested from the selected boreholes deviated from the WHO (2008) highest permissible levels and thus not suitable for drinking by humans.

Table 2: comparing the pH of the boreholes with WHO standards

Borehole	pH	Deviation from WHO standards	Inference
Mc01	4.71	-1.79	Acidic
Mc02	5.01	-1.49	Acidic
Mc03	4.50	-2.00	Acidic
ND01	9.50	0.3	Basic
Nd02	4.50	-2.00	Acidic

Dissolved oxygen

The mean dissolved oxygen levels in the groundwater ranged from 69.1mg/L to 146.1mg/L. Some of the boreholes exhibited a significantly high concentration in dissolved oxygen as compared to others. This could be attributed to nearness of the boreholes to the surface, allowing free circulation of gases in the groundwater. Dissolved oxygen concentration is a key test in water pollution control and waste treatment as is used to indicate the level of contamination and potability of water. According to Olumuyiva (2012), low levels of dissolved oxygen in water indicate microbial contamination or corrosion of chemical substances in the groundwater.

Table 3: dissolved oxygen levels of the boreholes

Borehole	Dissolved oxygen level
Mc01	69.1
Mc02	134.8
Mc03	146.1
Nd01	65.5
Nd02	117.0

The chemical parameters

Nitrates

In order to understand the distribution of nitrates in the groundwater, an aspect of altitude was introduced. This was so as to understand if altitude influenced the nitrates distribution in anyway. The selected boreholes had their nitrate concentration levels ranging from 1.1 mg/L to 3.8 mg/L in the high altitude region and 1.6mg/L to 6.7 mg/L in the low altitude region. The mean nitrate levels in the high altitude region was at 2.4 mg/l while that of the low altitude region was at 4.2 mg/L. There was no correlation between altitude and the level of nitrate in the groundwater. The nitrate levels in both the low and high altitude regions were within the WHO (2008) standard levels of 10 mg/L. High nitrate levels in some of the boreholes could be attributed to infiltration of water into the aquifer from runoff containing dissolved nitrates (Prasad et al., 2014). According to Suthra et al., (2009), there is an association between high levels of nitrates in groundwater and intensive agricultural activities in the same area. High nitrate levels in water past the recommended levels is known to cause blue baby syndrome in infants (WHO, 2011).

Table 4: comparing nitrate levels with WHO standards

Region	Mean nitrate levels	Deviation from WHO standard levels
High altitude	2.4mg/L	-7.6 mg/L
Low altitude	7.37 mg/L	-2.63 mg/L

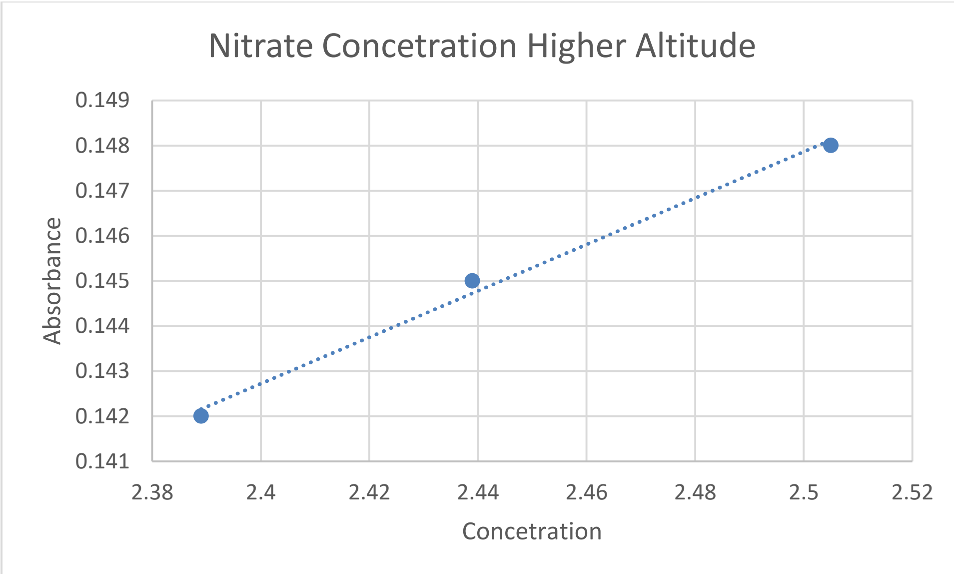

Figure 1: a graph showing high altitude nitrates concentration

A graph plot of the low altitude region nitrate concentration

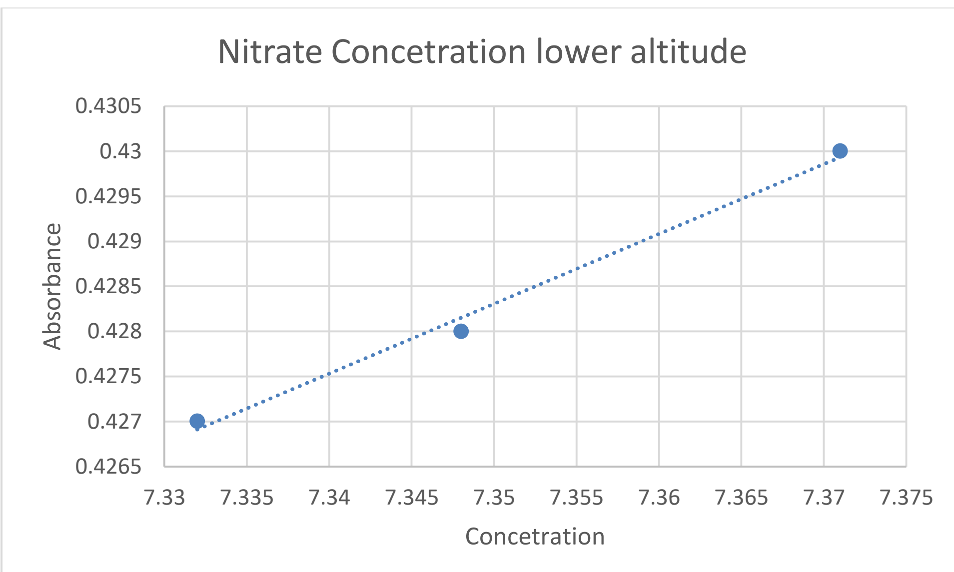

Figure 2: a graph showing nitrates concentration in low altitude region

Phosphates

The mean concentrations for phosphates in the study area were below detectable levels. This was the case with both samples from high altitude region and those from low altitude region of the study area. The low concentrations of phosphates could be attributed to geology of the area (Adeyemo et al., 2013). According to WHO (2008), high phosphates concentration has no health complications despite for its role in causing eutrophication in water bodies.

CONCLUSION AND RECOMMENDATIONS

Key physico-chemical parameters of the groundwater, that is, temperature and pH were significantly different from the WHO (2008) standards for drinking water thus making the water not fit for human consumption. This could be due to natural sources such as rock weathering and human factors such as poor management of septic sewage from urbanization.

based on the study results, the following suggestions are made.

i. There is need for good site selections for boreholes and wells in the Chuka area. It was noted that the boreholes were located too close to the urbanized areas where poor waste and sewage management could be influencing the quality of the groundwater.
ii. There is need to prevent the boreholes and wells from contamination by runoff. This can be done by properly sealing the boreholes to prevent entry of contaminated run off water.
iii. The local authorities need to ensure constant supply of clean piped water to the residents of the area to help safeguard their health. It was noted that the residents of the area usually turn to the borehole water when piped water supply grows short. Also, not all the residents of the have access to piped water, and so some rely on the groundwater entirely.
iv. A borehole management committee should be formed and trained as technicians to help repair minor damages in cases of breakdown.

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