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Assessments of selected heavy metals and physical-chemical characteristic parameters of selected community water boreholes in Loki char ward Turkana County, Kenya

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ABSTRACT

Underground water baseline studies are very instrumental in the provision of data for inventories that would play a critical role in conservation assessments and for future development project monitoring.This study was conducted in Turkana County.The main objectives of this study were to enhance the current knowledge and understanding of the water quality of the community boreholes,establish its portability, and provide baseline data that will be very useful to the water quality monitoring agencies. Water samples were collected from randomly selected boreholes in Turkana South Sub-county using fixed volume purge and sample technique and both field measurement and laboratory analysis by use of an Atomic Absorption Spectrometer were used in analysis of selected heavy metals. The sampled boreholes were Sale-yard, Nakukulus, ACS and Lokichanda boreholes. The study established that the levels of heavy metals such as Copper, Magnesium, Barium and Lead were all below the recommended levels by WHO. However, the levels of Iron and Nickel which were above the World Health Organization of 0.3mg/L and 0.2mg/L in the four community boreholes with recordings of (1.17ppm,1.5ppm,0.39ppm,0.3ppm) and (0.27ppm,0.63ppm,0.58ppm,0.37ppm) respectively. In addition, the Turbidity and TDS levels were also above the WHO-recommended levels of 5 NTU and <1000 ppm respectively. The Turbidity readings for the four boreholes were (6,6.3,5.5,4.9) NTUs respectively. The TDS levels for the four boreholes respectively were (1060,1020,1473,1025) ppm which were all above the WHO standard levels. There is a need to treat this water before consumption and perpetually monitor its quality to ensure the safety of the locals.

Literature Review

According to Oxfam (2017), Turkana County is the second largest of 47 counties in the Republic of Kenya, covering 71,597.6 km2 and accounting for 13.5% of the total land area in the country. Turkana County is located in the Northwest of Kenya and borders Uganda, South Sudan and Ethiopia.The Turkana people predominantly secure their livelihood from pastoralism and therefore water and vegetation resources are very important. However, this has come under pressure due to inter-related issues including the impacts of climate change, increased drought and continued environmental degradation. It is also important to note that the Government of Kenya has discovered oil and gas in Turkana County and specifically around the study area,in South Lokichar Basin (Mugendi etal.2021).The physiographic landscapes in the county comprises of low lying open plains, river drainage patterns and mountain ranges. Lake Turkana is situated in the eastern part of the county at an elevation of 1,181 feet above the sea level with the surrounding basin being elevated at between 1,230-3,000 feet. Loima, Mogila, Songot, Kailongol, Silale Lorengippi,Kalapata and Loriu, are the main mountain ranges of the county. The mountain ranges, due to their high elevation, are usually green, covered with condensed bushes and high woody cover (Ragon etal.,2019).The ranges support important economic activities such as grazing during the dry seasons. The hills found in the county are;Tepes, Lokwanamor, Lorionotom, Pelekech,Lokichar and Loima,Natudao and Kasoroi hills. Lotikipi and Kalapata open lying Plains are also found in the study area (Earthview,2012).

According to Ratemo etal., (2020) Rivers Turkwel, Tarach, Malimalite, Kerio, Kalapata and Lake Turkana form the main hydrology of the area. The Turkana County Integrated Development Plan 2013-2017 underscores that Lake Turkana is a natural heritage for the County and is the largest alkaline permanent desert lake in the world. The lake has no outlet and has reduced inflows and high rate of evaporation. The water level in the lake is subject to three or four tarns seasonal oscillations. River Omo, which is a permanent river from Ethiopia, drains into Lake Turkana.The lake is located on the eastern part of the county; it has a northern island, and has a wide variety of wild animals such as hippos, crocodiles and waterfowl. There are also numerous rivers that drain into the lake. These comprise of rivers Kerio, Turkwel and many more that are seasonal. There are several springs spread across the county, most sections of the lake zones and Turkana East. Other sources of shallow water are periodic rivers (luggas) and water pans. There are very limited water pans, and earth dams around the study area since many of them dry up during the dry seasons. The pans found during the study area were unable to hold water throughout an entire dry season. The only river that passes through Lokichar ward where the study was carried out is the seasonal river Wei Wei. Water is a scarce resource in Turkana County and communities in many far flung areas including Loki char Ward mostly depend on underground boreholes water (Turkana CIDP, 2017). Understanding the quality status of the community underground water is very imperative for the locals as this would ensure that they consume safe water. Elevated levels of heavy metals in drinking water can cause serious health implications (Kim a& Kumar,2019)

When one is exposed to toxic heavy metals and they find their way into the body, various things takes place happen including interaction or inhibition of some metabolic pathways (Wu etal., 2016,2017). The carcinogenicity of heavy metals has not been well studied but it is assumed to be due to their binding to the regulatory proteins that do cell cycle regulation, DNA apoptosis, synthesis and repair (Kim etal.,2015). When apoptosis fails due to heavy metals exposure leads to failure in basic cell defense. A study done by Mahurpawar (2015) elucidate that prolonged exposure to Mercury in drinking water leads to fatigue,weakness, anorexia and gastrointestinal functions disturbances. High exposures can cause spasm and tremors of the fingers, eyelids, lips and even the entire body which may culminate with hallucinations.Exposure to Mercury too leads to nervous system, kidney and liver damage. Ogwuegbu and Muhanga (2005) underscores that continued exposure to Lead according to the study causes toxic reactions in the neurological, haematological and renal systems,which results in brain damage,convulsions and death. Lead solutions have been documented to be carcinogenic to animals.Exposure to nickel leads to respiratory tract infections and skin allergic reactions and prolonged exposure may lead to cancer cases and neurological breakdowns and eventually death.

According to Fu etal. (2012) exposure to Cadmium may lead to anaemia, renal failure, pulmonary emphysema, bone fractures, kidney stones,retarded growth, respiratory tract infections,cancer,joints and back pain.Prolonged exposure to Iron leads to cardiovascular diseases and respiratory tract infections.Exposure to hexavalent Chromium leads to severe irritation of the respiratory tract systems, kidney damage, asthma and some cancer cases.Other effects of chronic exposure at high levels include lung cancer and skin infections.Gupta etal.(2017) observes that prolonged exposure to Arsenic can cause gastrointestinal disturbances,bronchitis,peripheral neuropathy,weakness, skin disorder and damage to the kidney, the liver and the nerves.

High levels of Sodium Chloride can tamper with the growth of embryos and fetuses which may lead to fetal death.It can also lead to poor development of the musculoskeletal system and cause eye, skin and upper respiratory system irritation(Bakke *etal.,*2012).

Asche & Lead,(2013) notes that salts can affect plants and vegetation growth by altering the soil pH and other soil chemical and physical structures.Higher levels of TDS leads to water tasting bitter,salty or brackish. Nevertheless, levels of total dissolved solids has been shown to affect animals much more than humans.In bodies of water,like rivers, elevated levels of total dissolved solids frequently harm aquatic species more.High levels of Turbidity in water can can interfere with disinfection process f water treatment.It can as well allow harmful pathogens to grow, and may indicate the presence of harmful microbes such as viruses,bacteria, and parasites.

Methodology

The data on water quality was acquired through field measurement and laboratory experiment method. It entailed quantitative data that was interpreted to give the qualitative aspect of the water component. The sample for physical properties of water analyzed in the field got collected by drawing one litre of water on site from the four boreholes and the P.H, and Turbidity parameters of the water were measured. In the analysis of the heavy metal contents and TDS, 2.5 litres of water samples from each of the four community boreholes were drawn thrice in the four boreholes on quarterly basis for one year and in total, 48 samples were collected in accordance to the WHO borehole sampling standards and procedure (WHO,2017).The water samples were put in sterile glass bottles and placed in an insulated light-proof box containing ice packs whose internal temperatures was 4-degrees centigrade and transported for laboratory analysis of the chemical properties, which purely focused on selected heavy metals concentration. The study adopted fixed volume purge & sample technique borehole sampling technique. According to Gorchev & Ozolins(2011),fixed volume purging followed by sampling, involves pumping of a volume of water usually 3 or more times from the well lining and then sampling gets done. This study adopted the fixed volume purge and sample method where three volumes of water were pumped out before sampling. The fixed purge volumes were minimized by checking for physical-chemical parameters stability as pumping was being carried out. The parameters tested were P.H and Turbidity. This technique is very efficient in routine monitoring of boreholes and the fact that the use of this technique can get deeper boreholes samples justified its choice. The parameters analysed include,water P.H, Turbidity, total dissolved solids, selected heavy metals which included; Copper, Nickel, lead, Manganese, Iron, Calcium and Potassium were analyzed using Atomic Absorption Spectrophotometry (AAS). Atomic Absorption Spectrometer's functioning principle is founded on the sample aspiration into the radiation and atomised when the AAS's light beam get focused through the flame into the homochromatic, and onto the detector that determines the amount of light taken in by the atomised portion in the flame. Different metals absorb different wavelengths. A source lamp made of that element is used, making the method moderately free from spectral or radiation intrusions. The level of energy of the typical wavelength absorbed in the flame is relational to the concentration of the element in the sample.The analysis got carried out in line with WHO (1997) guidelines. The samples preparation followed the WHO guidelines by carefully mixing them. The instruments used in sample preparations were:500 µL automatic pipette (1), 5.0 mL pipet ,(1) 100 mL volumetric flask, (1) 1000 mL volumetric flask, (1) 500 mL beakers, (7) 250 mL beakers of the five dry beakers, 250 mL of deionised water was added. Using the 500 µL automatic pipette of 0.0, 0.5, 1.0, 1.5, and 2.0 mL of each of the elements discussed below was added to each of the beakers and mixed thoroughly. The concentrations of these elements in these standards were calculated. The flames were set up in the atomic spectrophotometer as described per every element and every sample was analysed. The lead was analysed at a wavelength of 283.3 nm by Atomic Absorption Spectrophotometry with the aspiration of the sample into the oxidising air-acetylene flame. When the aqueous sample is aspirated, the sensitivity for 1% absorption is 0.5 mg/L, and the detection limit is 0.05 mg/L. Standard lead solution: 1.598g of lead nitrate is dissolved in about 200ml of water containing 1.5ml of concentrated Nitric acid and diluted to 1000ml of metal-free water to give 1ml = 1mg Lead. Copper was detected at a wavelength of 324.7

nm by AAS with the aspiration of the sample acetylene flame. When the aqueous solution (sample) is aspirated, the sensitivity for 1% absorption is 0.1 mg/L, and the detection limit is 0.01 mg/L. Standard copper solution 1g of copper salt was dissolved in 15ml of 1+1 nitric acid and diluted to 1000ml to give 1ml = 1mg copper**.** As for the Nickel, 1.273g of nickel oxide was dissolved in a minimum quantity of 10% HCl and diluted to 1000ml with distilled water to give 1ml = 1mg of nickel. A sequence of values ranging from 1mg to 5mg is formulated from the stock and analyzed.

Iron got assessed by preparing a standard solution for Iron,0.100g Fe $(NH_4)2(SO_4)_2$-$6H_20$ which was measured and transferred into a 500-mL volumetric flask. 10ml of 2M, H2SO4 and 50-mL of deionized water was added to dissolve the compound completely, and the flask got filled to the mark with deionized water. Iron best detected at Acetylene-air frame of wavelength 248.3 nm of the AAS.Calcium was assessed by preparing a stock solution for Calcium 0.252g of dry primary standard Calcium Carbonate. $CaCO_3$ got weighed and rinsed into a 100 mL volumetric flask with a few milliliters of deionized water. The stock was then dissolved in 6 m HCl and diluted to the mark with deionized water. The optimum range concentration of 0.2-7 mg/l got assessed at a wavelength of 422.7 nm. Potassium was analyzed by preparing a stock solution by dissolving 0.1907g of KCl (analytical reagent in deionized distilled water and filled up to 1 litre. Dilutions as aforementioned above got prepared and used in the calibrations during analysis.

The optimum concentration range of Potassium 0.1-2mg/l got detected at 766.5nm. Finally, on heavy metals, Manganese was analysed by preparing the Manganese reference solution, where 2.748 g of Manganese Sulphate was dissolved in 1000 ml volumetric flask in water. 5 ml of hydrochloric acid got added and filled up to the mark with water.The optimum concentration range of 0.003-1 mg/l detected at a wavelength of 285.2nm Acetylene-air flame.The standard stock solution of Magnesium which had 5ml of Nitric acid and 50ml of Caesam Lanthanum added into it was prepared.It was then aspirated together with the sample at the wavelength of 279.5nm on Air-acetylene flame.In detection of Barium,a standard stock solution of Barium which had 1ml of Nitric acid and 10ml of Caesam Lanthanum added into it was prepared.It was then aspirated together with the sample at the wavelength of 553.6nm on Nitrous-oxide-acetylene flame. Other physical properties of water such as; Turbidity,tTotal dissolved solids, and pH were also determined. The pH and the Turbidity were established in the field using the pH. Metre and Turbido-meter respectively.The pH determination entailed the measuring of the Electro-Motive Force (E.M.F) of a cell involving an indicator electrode dipped in the test solution and the reference electrode which mostly is made up of mercury.

The interaction between the test solution and the reference electrode is usually gotten using a liquid junction, which forms a part of the reference electrode. E.M.F of this cell was determined by pH meter, that is, a high impedance voltmeter calibrated regarding pH.The electrode is allowed to stand for 2 minutes in a 1 Litre water sample in a beaker to stabilise before taking reading for reproducible results (at least ±0.1 units).The readings got read in the field according to the WHO guidelines (WHO,2002).The water Turbidity was also determined in the field using the nephelometer. The nephelometer was standardised using distilled water (Zero NTU) and a standard Turbidity suspension of 40NTU. The carefully shaken sample got placed in the nephelometric tube, and the value documented. Turbidity (NTU) = (Nephelometer readings) (Dilution factor).As for the Total Dissolved Solids, it was determined by filtering 1000 ml of the water samples through a glass fibre filter disk. The filtrate got collected in an already weighed evaporating dish. The water samples were then evaporated until they dried up at 104^{o} C and then put in an oven at 180^{o} C.The weight of both the residue and the dish were determined, and the residue mass determined by the Equation

$$\mathrm{MgTDS/L} = \frac{\text{Weight final(g)} - \text{Weight initialn(g)}}{\text{Sample volume (ml)}}$$

Results and Discussion

Table 1.1 above shows that, the PH of the samples collected had slight variations across the four boreholes. The average PH for the four boreholes as per the year 2022 was 7.96. Though there is no cause for alarm, since the P.H of the water is within the World Health Organization limit for drinking water of 6.5-8.5, it is imperative to ensure that any acivity in the area of study that can alter this PH, is closely monitored for the health and the safety of the locals.The mean water Turbidity from the four boreholes was 5.68 NTU in the year 2022. High Turbidity can arise from the disposal of waste material into the water body. The average water Turbidity of the sampled boreholes was 5.68 NTU, and this surpasses the World Health Organisation limit of 5NTU per litre.According to Atekwana etal..(2004),total dissolved solids come about due to dissolved hydrocarbons, selected heavy metals, acidic salts, volatile organic compounds and other inorganic compounds.The main sources of increased turbidity in drinking water can be dissolved solid materials such as the heavy metals, Sulphates salts, Bicarbonates and other hydrocarbons. The hydrocarbons could be from grease, oil, and dissolved organic compounds such as Naphthalene, Phenathrene, and Pentach: Benzene, Toluene, and

Pentachlorophenol.One primary source of the noted increased TDS in the underground water could be infiltration of surface runoff that has dissolved matters from poorly disposed waaste materials that are organic in nature.The study established that there are drilling of oil and gas hydrocrbons around the study area and this can be assumed to contribute to the mentioned origin and infitrated dissolved organic and heavy metals phenomena.The levels of the TDS was way much above the World Health Organisation limit of less than 1000mg/L.This situation if not managed may lead to health challenges to both animals and humans due to the specific components such as Benzene and other hydrocarbons and heavy metals whose in excess levels are toxic. Bioaccumulation of Benzene and other hydrocarbons as noted by Ajugwo (2013) has been linked to colon and respiratory infections including cancer.

Table 1. Selected Heavy Metals Concentrations and Selected Physical characteristics of Community Boreholes

Boreholes	Acs community Borehole	Lokichada Borehole	Saleyard Borehole	Nakukulus Borehole	
Ph	8.09	7.71	8.06	8	6.5-8.5
Turbidity	6	6.3	5.5	4.9	5
Fe	1.11	1.17	1.5	0.39	0.3
Ba	0.01	0.03	0.02	0.01	0.3
Mn	0.01	0.02	0.03	0.02	0.1
Cu	0.02	0.02	0.09	0.03	2
Ca	12.25	15	16	9.89	<100
Mg	45.4	32.3	28.2	19.5	50
K	2.4	2.92	6.06	3.59	No limit
Ni	0.27	0.63	0.58	0.37	0.02
Pb	0.00	0.00	0.00	0.00	0.01
TDs	1060	1020	1473	1025	<1000

The Atomic Absorption Spectrophotometry used in the analysis of the water sample detected levels of heavy metals such as Copper, Magnesium, Barium and Lead that were below the recommended levels by WHO. However the levels of Iron were way much above theWorld Health Organisation of 0.3mg/L since the analysis recorded the average levels to be 1.0425 mg/L.The high levels of Iron can as well be associated with the oil and gas drilling actvities taking place in the area,however this study can not with certainity concclude that hence the need for more studies to establih the causal effect.This is because Knez *et al*. (2006) oberves that drilling muds that are normally used in oil and gas drilling are typically combined with Barite to increase their density during drilling activities and that, these Barite have a lot of impurities inform of selected heavy metals and Iron is a crucial component.

The level of Iron is alarming because according to Grazuleviciene *etal.*(2009), ingestion of Iron by animals and humans produces free hydrogen radical, that attack the DNA, and this causes damage to the body cells, mutation and malignant diseases such as cancer of the colon and respiratory systems. In addition prolonged exposure to Iron may lead to cardiovascular diseases and respiratory tract infections.Exposure to hexavalent Chromium leads to severe irritation of the respiratory tract systems, kidney damage, asthma and some cancer cases.There is aneed for more investigation on the levels of Iron metal concetration of the community boreholes to avoid dentrimental health effects of the locals.The average levels of calcium in water samples of the boreholes was about 13.29mg/L while the average levels of Magnesium increased was 31.35mg/L.Both metals level is within the World Health Organisation limits of < 100mg/L and <50mg/L respectively.The water samples levels of Potassium were below 5mg/L.Potassium has not been reported to have any significant side effects if overdosed in the human body and thus there is no limit for it's in drinking water according to World Health Organisation.

The most striking element identified in the samples of the four boreholes that were sampled was Nickel.The average levels detected by this study was 0.46 mg/L.This concentration of Nickel in drinking water is way much above the World Health Organisation's limits of 0.02mg/L.Again this study attribute the elevated leves of Nickel to the oil and gas drilling activitie around the community boreholes.This is because according to Mbithe(2016) drill cuttings waste materials are very rich in selected heavy metals such as Nickel and if not managed correctly they ends up polluting water aquifers.

Short and prolonged exposure to Nickel has serious health implications to both animals and human beings according to Duda-Chodak & Blaszczy (2008).They noted that exposure to Nickel is highly associated with dermatitis skin infections, nasal and lung cancer infections and other respiratory problems.The study assumption and association of the elevated nickel heavy levels with oil and gas dilling activities is consistent with the findings of Kadafa and Ayuba (2012) who noted that,the use of Barium Sulphate as a density enhancing agent for the drilling fluids and pressure balancing agent has been the primary source of heavy metal pollutants in soil and water.He adds that Barite has a lot of impurities of heavy metals and if the surface runoff washes these impurities or form leachate from the mud cuttings, they end up polluting the underground water resource.The elevated levels of TDS had affected the taste of water and it tasted abit salty.High levels of Turbidity in water had the potential of interfering with disinfection process of the underground water .

Conclusion

The study established that the levels of heavy metals such as Copper, Magnesium, Barium and Lead were below the recommended levels by WHO. However the levels of Iron and Nickel were above theWorld Health Organisation of 0.3mg/L and 0.2 mg/l respectivly.The water Turbidity and TDS of the four boreholes were as well above the WHO recommended standards and this calls for the need to treat this water before consumption.Assesing the quality of ground water is a very important exercise for Turkana County communities in Kenya.This is because underground water is the main source of communities water.As indicated heavy metals forms the major source of undergground water pollution.Geological formations and human activities such as mining and oil and gas extraction are major sources of underground water pollution.Upon exposure of humans and animals to the heavy metals contaminated water through ingestion or occasionally dermal exposure the heavy metals are retained and they accumulate in the human body tissue and may cause serious health effects.Even though most of the assesed heavy metals of the selected community boreholes in Lokicchar Ward are within the recommended standard there is a need for the drinking water to be treated and filtered.Some health effects that may arise from exposure to heavy metals as indicated include physiological effects on kidney, digestive system,circulatory system and nervous system.Heavy metals can also affect cellular process such as cell growth, differentiation, proliferation,damage-repairing processes and apoptosis.This emphasizes the need to keenly asses the potability of underground drinking water in Lokichar Ward and other parts of Turkana County to reduce the harmful effects and save lives in the long term.

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Conflict of Interest

The authors have no conflicts of interest to declare. The co-author has seen and agreed with the content of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication

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