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**Research Article**

# Situational Analysis of Groundwater Resources in Kenyan Drylands, Case study of Turkana County

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## Abstract

Recent climate changes have increased the incidences of severe droughts and floods, which have increased the vulnerability of pastoralists in the Kenyan drylands. Thus, there is a need to carry out a situational analysis of groundwater as it is the main source of water which provides baseline information useful for planning Analysis of results indicates that Turkana County is dominated by shallow wells and boreholes with the shallowest wells located along the seasonal rivers and Lake Turkana. The borehole depth was found to range between 20 to 200m. Most of the boreholes located near Lake Turkana were shallower compared to those far away from the lake with a depth ranging between 0 to 52m. Most of the boreholes had a low yield that ranged between 1.2 to 4.6m3/hr be attributed to the basement rocks which are prevalent in the county and are classified as poor aquifers. The water points were mainly dense in urban areas, which was mainly the central region where the water demand was high and this was attributed to the high population. The groundwater levels occurred mostly at 13m indicating that Turkana County has mostly shallow aquifers that predominantly occurred along the river valleys and at the edge of the volcanic deposits. The groundwater quality is mainly saline as most of the boreholes had high TDS, EC and chloride levels. The presence of high fluoride levels indicates the presence of high volcanic rocks that have high fluoride ions that are largely prevalent in the study region. The Sulphate, Nitrite and Nitrate Levels in all the water samples analyzed were below the EU, WHO and KEBs standards indicating the low anthropogenic activities carried out in the drylands as most farmers are pastoralists. The most prevalent cation was sodium in some of the boreholes indicating why the groundwater was saline.

**Keywords:** Groundwater. Water quality. Water levels, Climate change, Boreholes

## Introduction

Groundwater is the main source of water across Africa and there is a continuing effort to quantify and map the groundwater resources and recharge rates (MacDonald, et al., 2021). At the same time, climate change remains a major threat and challenge to the supply of this water affecting water security and thus food security. Indeed, studies (e.g. (Kang, et al., 2009; Feitelson and Tubi, 2017; Ülker et al., 2018; Naderi, 2020) have indicated that water security is the main variable that is affected due to climate change. Moreover, water plays a key role in adapting to climate change and is fundamental to attaining goals set by Africa Water Vision 2025 and aims to fulfil the 2030 Agenda for Sustainable Development and the Kenya Vision 2030 (Asokan et al, 2020). Recent climate changes have increased the incidences of severe droughts and floods, which have increased the vulnerability of pastoralists in the drylands. Thus, there is a need to carry out a situational analysis of groundwater because of the changing climate in the Kenyan drylands where the majority populace is facing starvation. This includes understanding rainfall variability patterns and the current status in terms of quality and quantity of the water underground in the face of growing demand.

## Materials and Methods

### Description of the study area

In Kenya the Turkana County is considered vast located in the North-west part of Kenya with an area coverage of 77000 km2 and is approximately 43% of the total areal extent of the Kenyan rift valley. Some of the physical features include Lake Turkana which constitutes the natural eastern border of the county. The county comprises of six districts namely; Turkana North, Turkana West, Turkana Central, Loima, Turkana East and Turkana South (Figure 1). This county is among the poorest areas often marked with frequent droughts and famines. Besides the famine, the populace is faced with droughts that repeat in cycles of a two-year period. This results in the drying of the water resources and leads to reduction and pressure on the perennial water points resulting in epidemics and outbreaks of diseases among both the people and the livestock (Oduor, et al., 2012).

### Rainfall and Temperature patterns

The constituent districts of North, central and South have characteristics of the arid and semi-arid lands. The distribution of the annual precipitation is said to be concentric and the mouth of River Turkwel is the center spreading out to Lake Turkana..

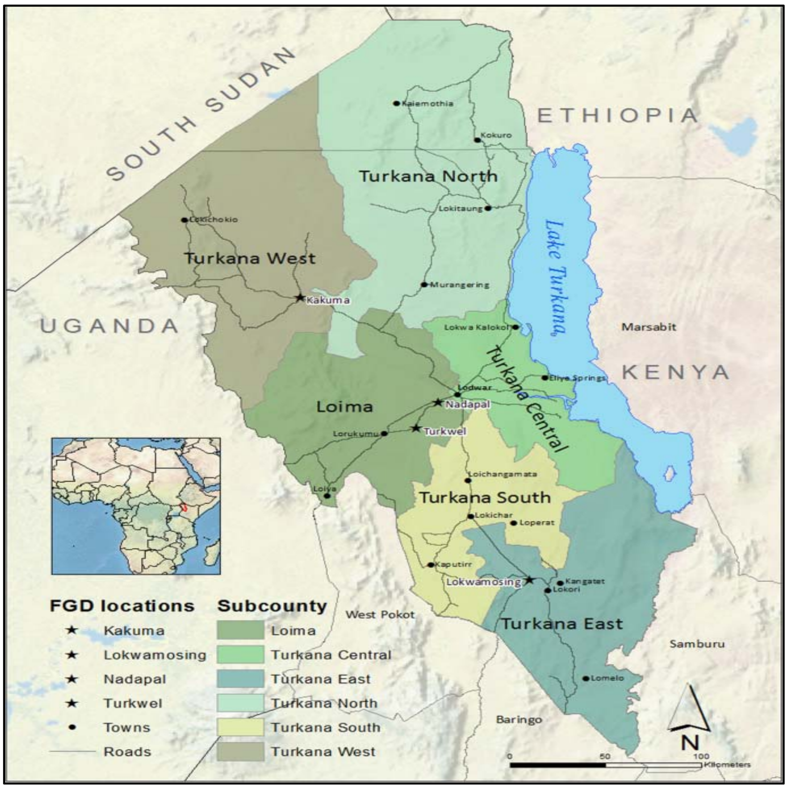


Fig. 1: Map showing the Turkana County

The minimum precipitation amount is received at downstream of River Turkwel and is usually below 200mm/yr (JICA, 2013). Figure 2 illustrates the rainfall variability and the drought years. The highest amount of precipitation is received in the mountainous range bordering Ethiopia and is usually greater than 900mm/yr. The long rains are received in the month of March April and May (MAM season), and the season of short rains is experienced in October, November December (OND season). Generally, as the surface elevation increases in the region, the rainfall amounts received also increase while the temperatures reduced with the increase in the altitude. Nevertheless, the rainfall pattern and duration have been highly variable, unreliable and stochastic varying over the years (Figure 3). The spatial distribution of rainfall is as seen in Figure 4. Temperatures are high as one move from River Turkwel towards Lake Turkana where the mean temperature is approximately 28°C. In the mountainous region towards the Uganda and Ethiopia border, low temperatures of below 22°C are experienced. The mean annual temperature lies between 26.2°C - 24.1°C with an average of 30.2°C(Figure 5). The spatial distribution of the rainfall was as seen in Figure 4

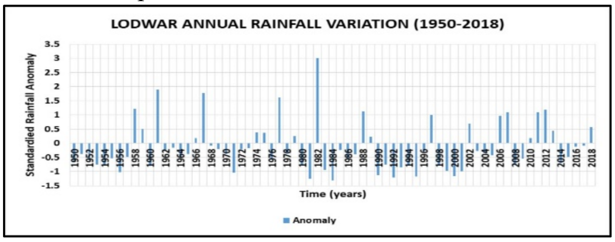


Fig. 2: Lodwar Annual Rainfall Variation (1950-2018)

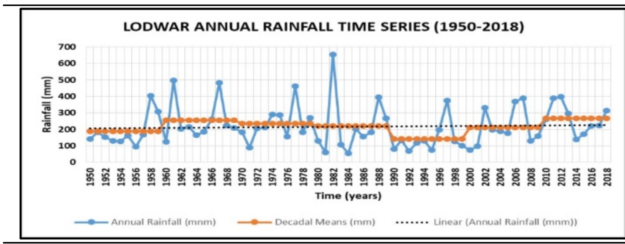


Fig. 3: Annual Rainfall time series (1950-2018)

The methodology involved both the detailed desktop reviews from existing documents and field visits were done for primary data collection. The documents reviewed included examining of existing data, topographical maps, climate maps, existing studies and borehole site investigations in the area, and geological reports. Some of the key reports evaluated included:

- The JICA report-which looks at the water prospects in Turkana County (JICA, 2013).
- Environmental and Social Impact Assessment (ESIA) 2020 for South Lokichar oil development.
- A report that looks at the detailed study of the underground water in Turkana (UNESCO, 2013)
- The Project on the Development of the National Water Master Plan 2030 in the Republic of Kenya, (JICA, 2013).
- Kenya Acacia Rapid data reports (2015) (2015)

Field visits were done in Turkana County to ground truth the secondary data especially on the available groundwater sources and their management. In addition, Stakeholder interviews, Focus Group Discussions were done with key informants. Observations were also done and existing condition of sources done.

## Results and Discussions

### Water supply and management

The predominant rivers in the region are river Turkwel and Kerio, which both originate from the highlands that are in the south. There are also seasonal rivers in the region which are commonly called "laggas". The region can be divided physio-graphically into five sections, namely: - Uganda Escarpment, The Mountain Ranges, The Plains, Lotikipi Swamp, and Lake Turkana Coastal Plain. The water supply is mainly done by the government pipeline called LOWASCO which mainly distributes water in the urban centre of Lodwar and the surrounding environment to a span of 50 km. Other Water Service Providers (WSPs) are available in the region but the rural water supply is mainly groundwater from the boreholes and shallow wells The region has a variety of water sources which are indicated in Table 1 and Figure 6. It was observed that the main water sources especially the shallow wells were mainly distributed along the main River Turkwel and kerio River.

The linear distance from human settlement to the water points varies significantly depending on the area but is mostly between 5 – 10 km. Settlements in the urban zones and adjacent market centres enjoy fairly a good water supply as the Water Providers have piped the water to the majority of the settlements, therefore they rarely experience water shortage problems. (KNBS/SID Report).

Averagely 61% of rural homesteads have access to poorly constructed water sources which include unprotected wells and streams. Nonetheless, the wide extent of these homesteads is located in the northern district of Turkana which studies indicate that 60% of rural homesteads depend on undeveloped water sources (VWM Report, SNV 2014). Unrestricted sand harvesting has resulted in acute environmental dilapidation advancing the transformation of some river regimes and the dropping in the ability of the rivers to retain water and store the water in the intermittent rivers.

Table 1. Water points in Turkana (SNV-report 2014)

| Improved water type | No. of water point |
|---|---|
| Borehole | 214 |
| Protected dug well | 86 |
| Piped water into the home | 73 |
| Public water/kiosk | 45 |
| Sand dam with a well | 20 |
| Rainwater harvesting | 7 |
| Rock catchment | 5 |
| Protected springs | 3 |
| Unspecified | 4 |

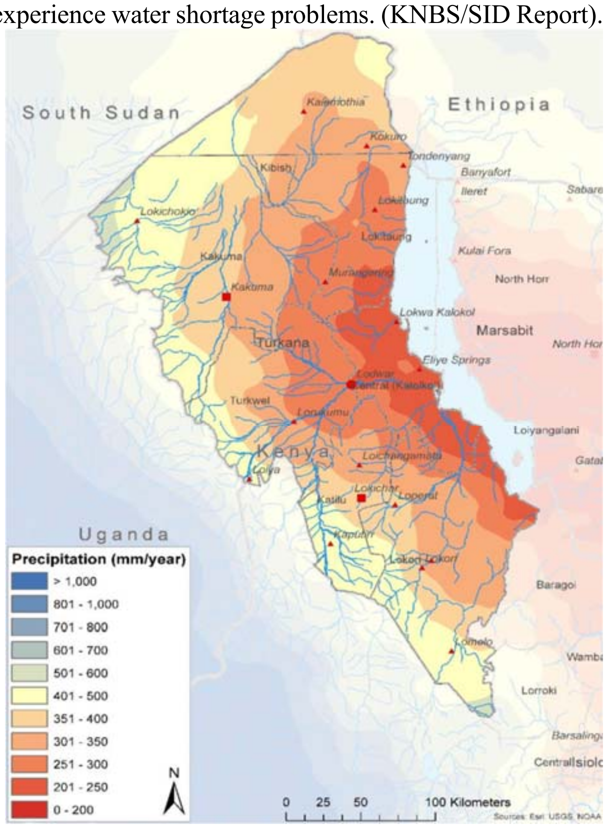


Fig. 4 Spatial Rainfall distribution of Turkana
*Source: Documents (acaciadata.com)*

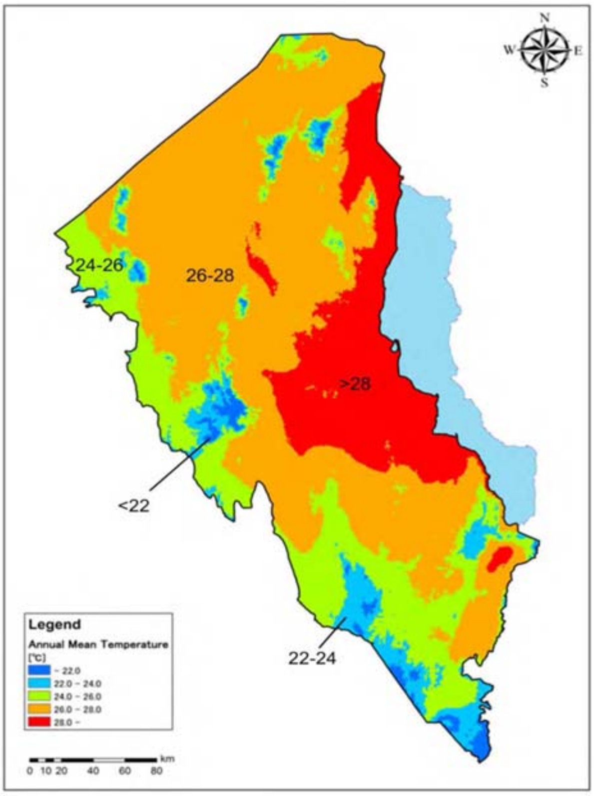


Fig. 5: spatial Temperature distribution of Turkana
*Source: JICA project team (2015)*

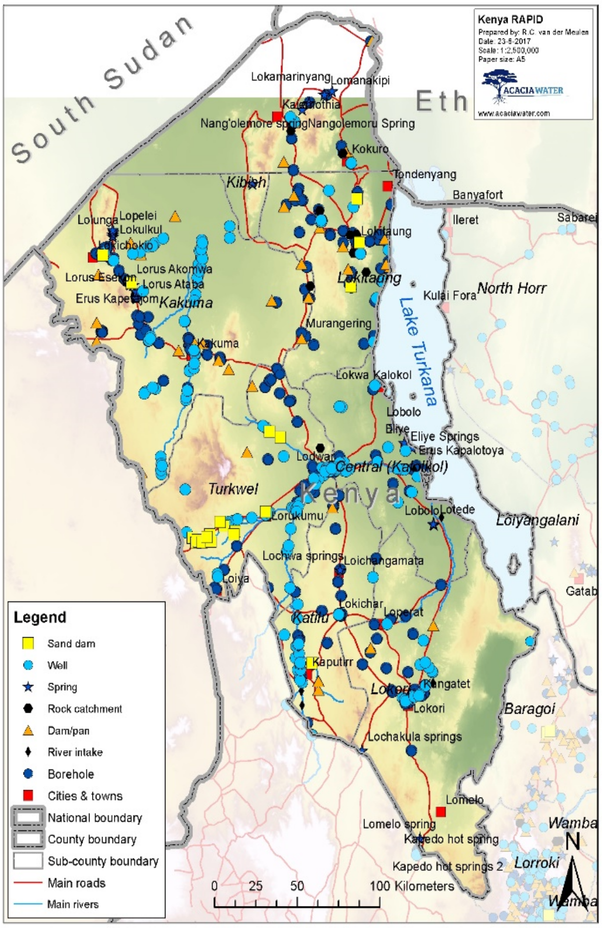


Fig. 6: the distribution of the water sources
*Source: Acacia, (2015) Documents (acaciadata.com)*

**General Hydrogeological Characteristics**
The geology of the study area (Figure 7) was obtained from secondary sources (JICA *ANNEX E Water Potential Study In Turkana County)*

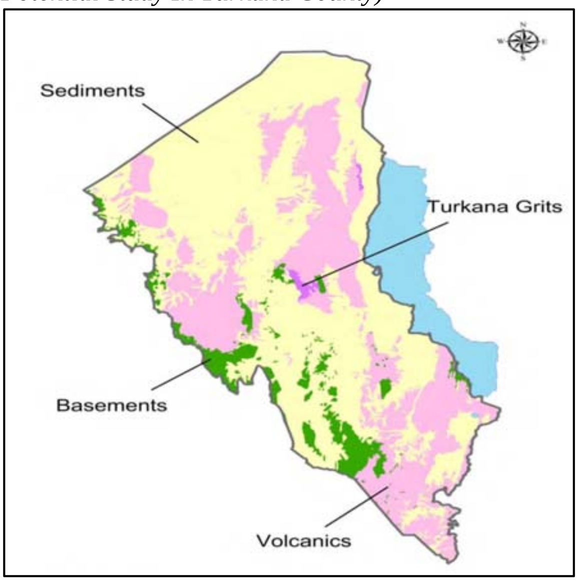


Fig. 7: Geology of Turkana County
*Source: JICA Annex E-report (2015)*

Basement Systems is towards the west of the county consisting of granites metamorphic rocks and limestone which is well developed especially towards the Uganda Escarpment. Turkana Grits is made up od very hard metamorphic rocks and sandstone and is towards the Laje Turkana region. The volcanics are towards the south and sediments in the North. The topography of the region is undulating marked with the hills and flat areas (Figure 8)

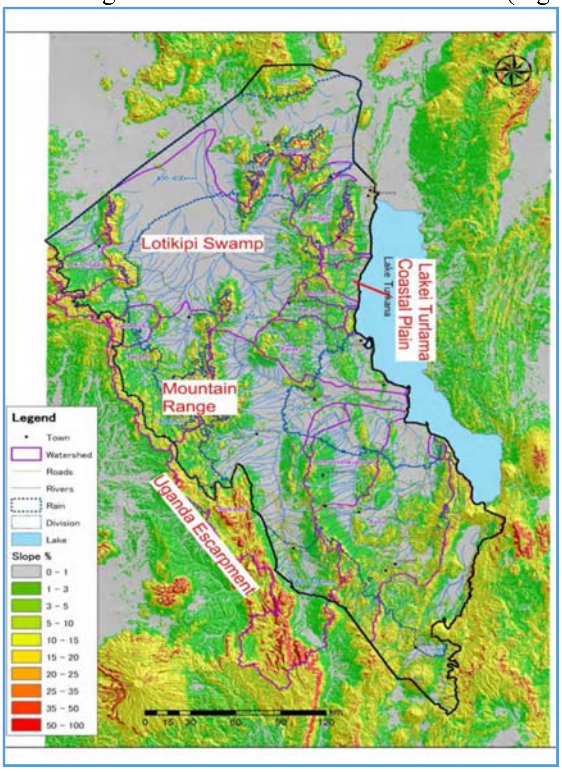


Fig.8: Slope and topography of Turkana County
*Source: JICA Annex E-report (2015)*

The secondary data analyzed from JICA report 2013 revealed that the potential ET from soil is more than 2,000mm/yr corresponding 2 to 10 times of rainfall indicating very low recharge rates for groundwater (JICA, 2013). The Potential groundwater ET was more the 1500 mm/year which implies that most groundwater especially from shallow wells evaporates back to atmosphere.

**Borehole Depths and Yield**

The borehole depth was found to range between 20 to 200m. Most of the boreholes located near lake Turkana were shallower compared to those far away from the lake with a depth ranging between 0 to 52m (Figure 9). It was also observed that most boreholes were located around towns. The results agree with the findings reported by the ESIA (2020) which indicated that Lodwar Town draws its water supply entirely from boreholes near the banks of the Turkwel River attributing this to urban population settlements.

The results highlighted that the borehole yield ranged between 1.2 to 14.6 $m^3$/hr, as shown in Figure 10. Most of the boreholes had a low yield that ranged between 1.2 to 4.6$m^3$/hr. The results also showed that the boreholes at Kakuma, Lorukumu, Loiya, Loichangamata, Lokichara and the area surrounding Lokori had yield values ranging between 4.6 to 7.9$m^3$/hr; meanwhile, one borehole showed a yield value ranging between 7.9 to 11.3m$^3$/hr. The low yield in boreholes could be attributed to the basement rocks which are prevalent in the county and are classified as poor aquifers (ESIA, 2020).

***Water Demand and Source Distribution***

The water demand in Turkana County is relatively high (Figure 11). Regions furthest from Lake Turkana registered much higher water demand compared to those near the lake.

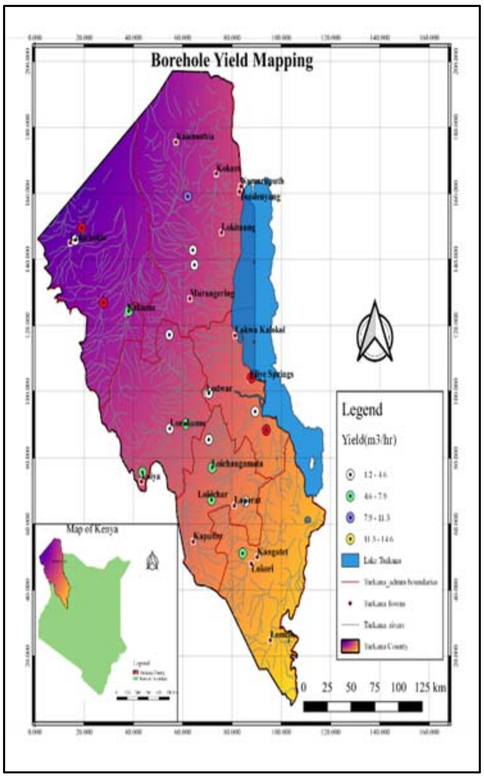


Fig. 9: Borehole depths in Turkana County

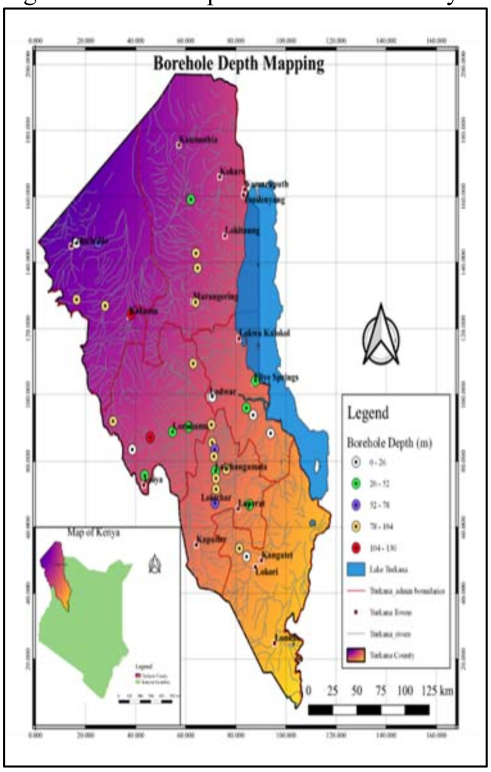


Fig. 10: Borehole yield in Turkana County

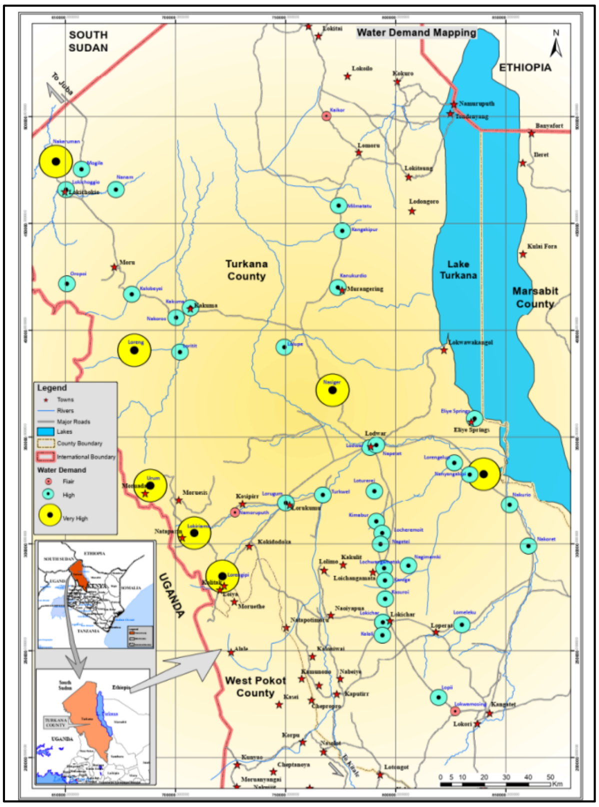


Fig. 11 Water demand in Turkana County (2016)

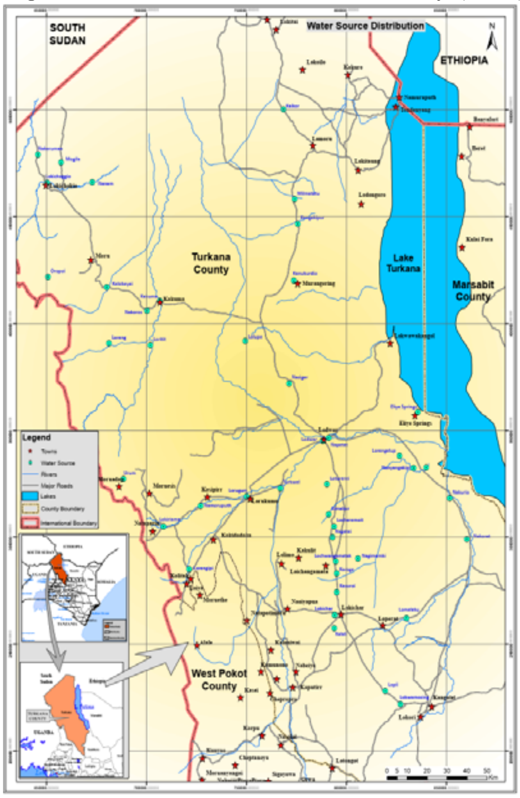


Figure 12: Water source distribution

This could be attributed to the fact that the population near the lake use it as a source of water and economic livelihood. The sources of water were mainly dense in urban areas, while rural areas lack water points as highlighted in Figure 12. Northern Turkana has the least number of water points which could be because of the reliable rainfall received in the region given that it is mountainous The central region which is largely urban had the highest number of water sources which could be attributed to the high water demand that was pressurized by high population growth, socio-economic activities, insufficient piped water services and changing consumption patterns in the urban centres (Maxwell et al, 2020).

***Groundwater level Mapping***

The distribution of groundwater levels in Turkana County from sampled boreholes was as seen in Figure 13. The results showed that the water level in most of the boreholes was below 13m; only one borehole in Lokichogio registered a water level of 64m, while the other water levels ranged between 1.5 – 38m indicating the presence of shallow aquifers. The findings agree with ESIA, (2020) which indicated groundwater was typically encountered at depths between 20-40m; and that Turkana County had mostly shallow aquifers that predominantly occurred along the river valleys and at the edge of the volcanic deposits. Additionally, the results revealed that the Lodwar aquifer depends on local precipitation for recharge, which is usually low as the county receives precipitation less than 250mm. According to results by Tanui (2020), Lodwar has three interconnected freshwater aquifers namely; the shallow, intermediate and deep aquifer systems jointly called the Lodwar Alluvial aquifer system. The fourth is the Turkana Grit Shallow Aquifer known to be mainly saline. Further significant recharge is derived from the apparently permanent Turkwel River that originates from Mount Elgon located in the southwest. The direction of underground flow is mainly influenced by the surface topography The direction of the base underground flow is west to east (Swarzenski and Mundorff 1977; MWI 2005). The surface run-off is majorly from high altitudes of volcanic and metamorphic slopes toward the alluvial plains of River Turkwel (Tanui, 2020)

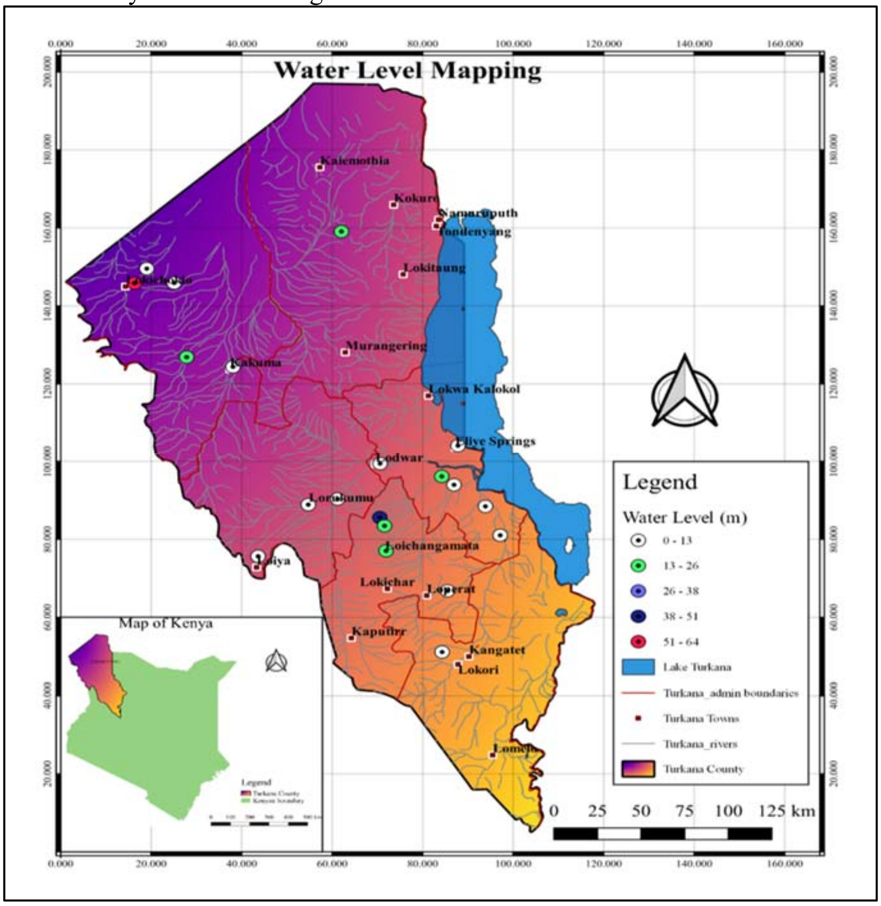


Fig. 13: Ground water level in Turkana County

**Physical Chemical Groundwater characteristics**
***TDS/Electric Conductivity/Chloride levels***

The TDS in all but four of the water samples in Turkana County were below the KEBS, WHO and EU recommended standard of 1000 mg/l(Figure 14). Water samples from Kalemunyang, Katilu, Lwarengak and Nalemsekon were above the recommended standards. The EC level in the boreholes was on average high ranging between 751 to 2251 mg/l. Only one borehole had a low EC level while the rest ranged between 51 to 600 mg/l (Figure 15). The high EC level suggests that most of the water points in Turkana are salty which explains why the TDS was high in some boreholes. Research by Ndegwa and Kiiru (2010) indicates that in the ASALs, salts accumulate in situ due to low amount of rainfall experienced. This is also related to the high chloride levels in Kalemunyang, Katilu and Lokitaung shallow wells whose concentration was beyond the recommended standard of 250mg/l. ESIA report (2020) also notes that Occasional exceedances of the chloride standard were observed in their sampled wells. High salinity predominates the Turkana grit, and is dominated by Ca–$HCO_3$ water type and Na–Cl water type (Tanui et al, 2020).

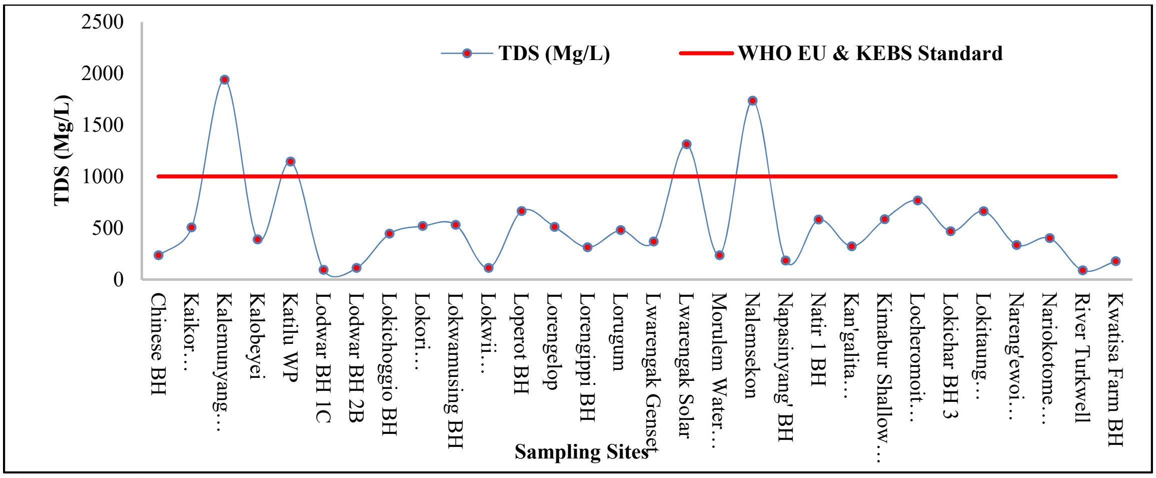

Fig.14 TDS levels in the water samples (2013)

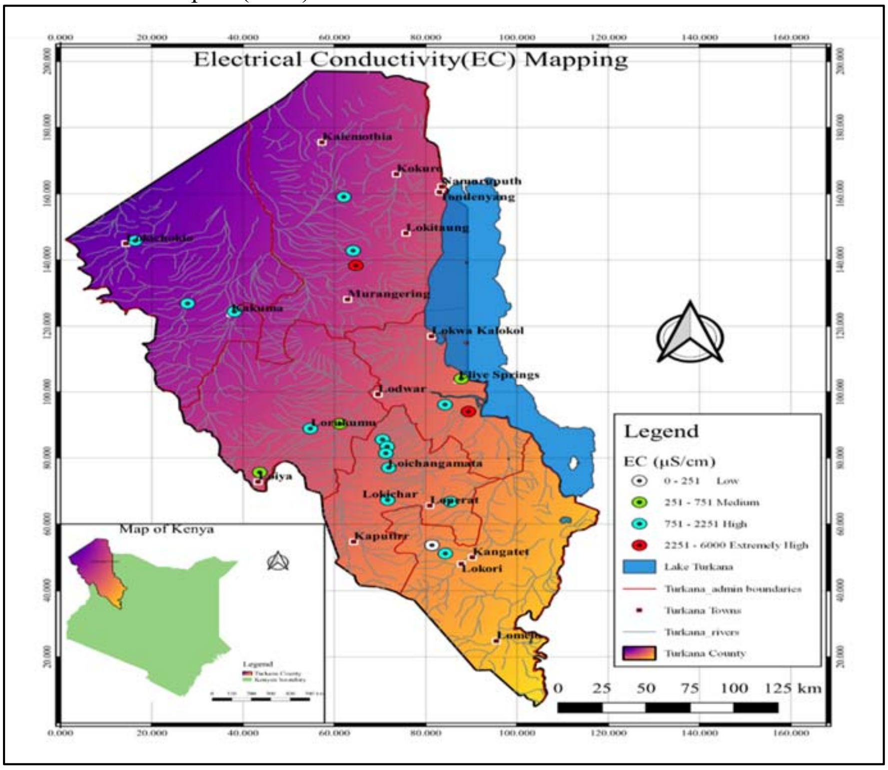

Fig. 15 EC level in Turkana County (2016)

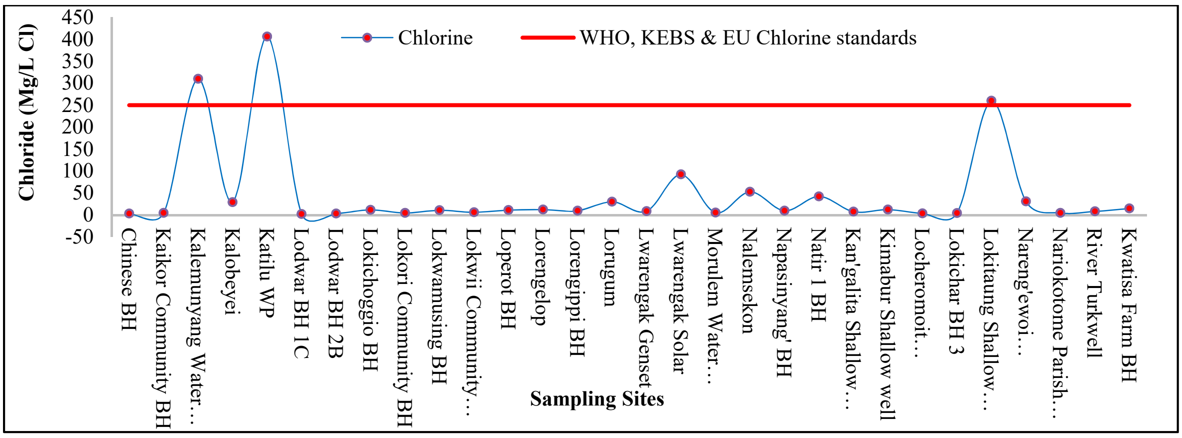

Fig. 16: Chloride levels in Turkana county

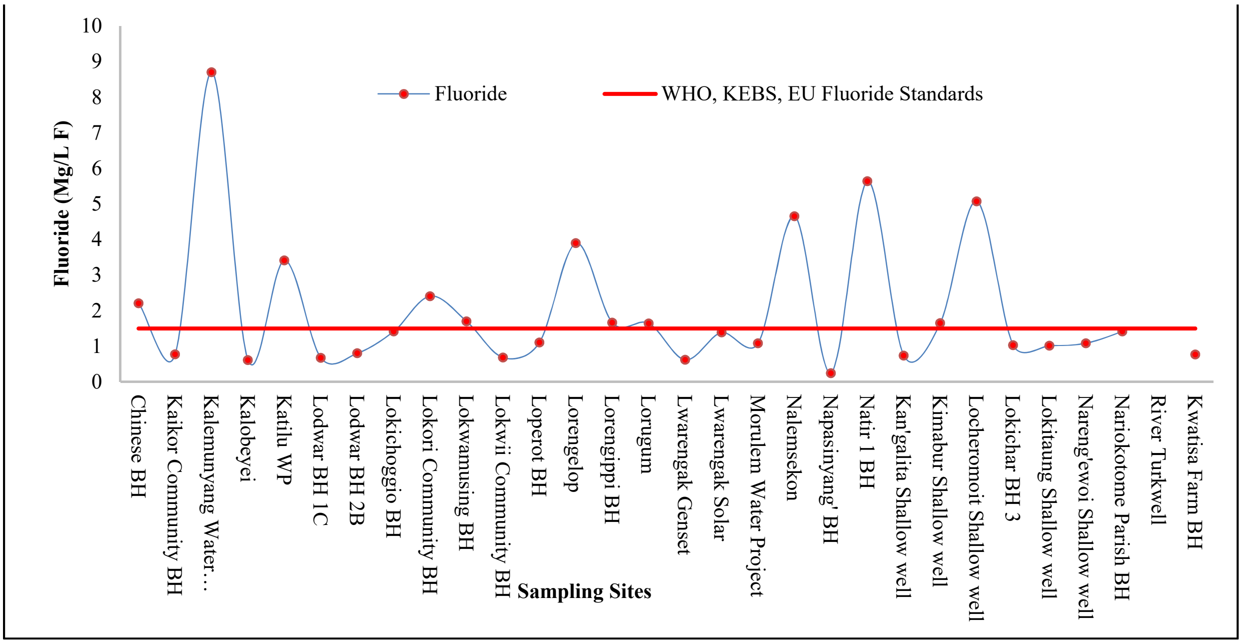

Fig. 17. Fluoride levels based on set standards (2013)

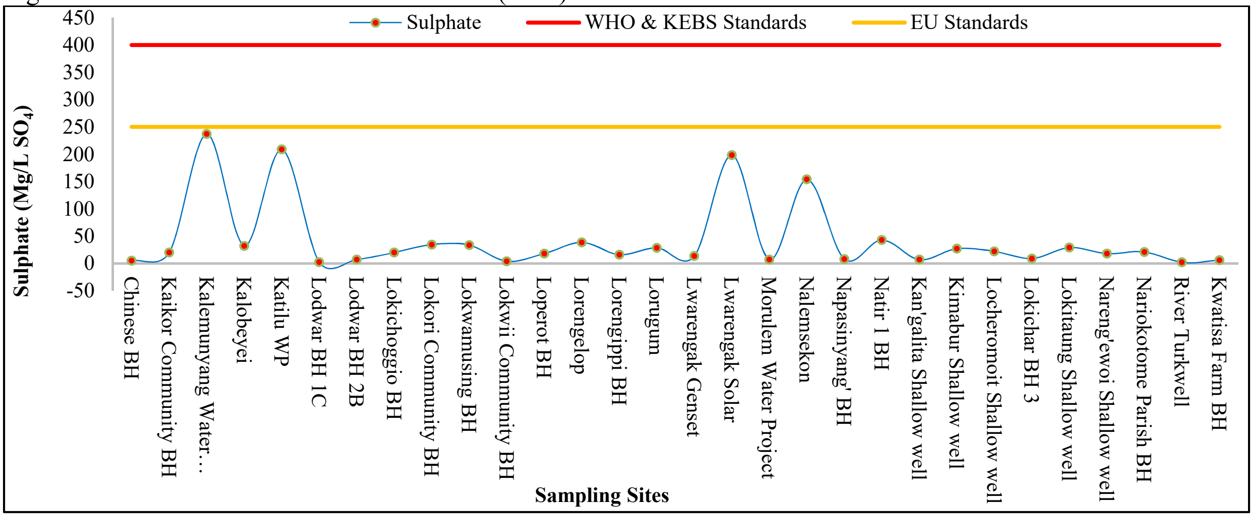

Fig. 18. Sulphate levels in the water samples (2013)

***Fluoride Levels***

Most of the water points in Turkana County had fairly high fluoride levels that ranged between 0.5 to 1.5 mg/l (Figure 17). Rusiniak et al (2021) had the same arguments that, fluoride constitutes fairly high amounts, (0.15 to 5.87 mg/L) which is the main problem in analyzed groundwater samples and was evident as skeletal fluorosis is quite prevalent in Turkana County. The high fluoride levels could be attributed to the geological formation of high volcanic rocks that have high fluoride ions that largely prevalent in the study region.

***Sulphate, Nitrite and Nitrate Levels***

The sulphate concentration in all the water samples was below the WHO and KEBS recommended drinking water standard of 400mg/l and EU standard of 250mg/l (Figure 18). The nitrate concentration in all the water samples was below 50mg/l and WHO standard of 10mg/l (Figure 19). The nitrite concentration (Figure 20) in all the water samples was below 0.1 mg/l which is the recommended standard except for the water samples of Katilu and Loperot. Anthropogenic activities determine the water quality and levels of nitrate, nitrite and sulphate are coupled to these human activities in addition to microbial reactions that happen in the aquifer that could contribute to high levels (Lapworth et al., 017). These findings imply that there are low human activities especially the lack of agricultural activities due to arid conditions and most Farmers in Turkana County are pastoralists.

***Metal concentrations***

Metal concentrations in Turkana county were generally below the selected water quality standards though there was occasional exceedance of the selected water quality standards for sodium. In three of the water samples analyzed sodium was below the WHO and KEBS drinking water standards of 200mg/l and 180mg/l EU standards (Figure 21). Kalemunyang, Lwarengak and Nalemsekon water samples are the only ones that were above recommended standards. These boreholes also had high TDS, EC and Chloride levels indicating the presence of salts in these areas. Tanui et al (2020) suggests that Sodium in normal waters is derived from the dissolving of feldspars or cation exchange reactions and that salinity is prevalent in the shallow Turkana grit. This is true as some parts of the Turkana contain these sedimentary rocks.

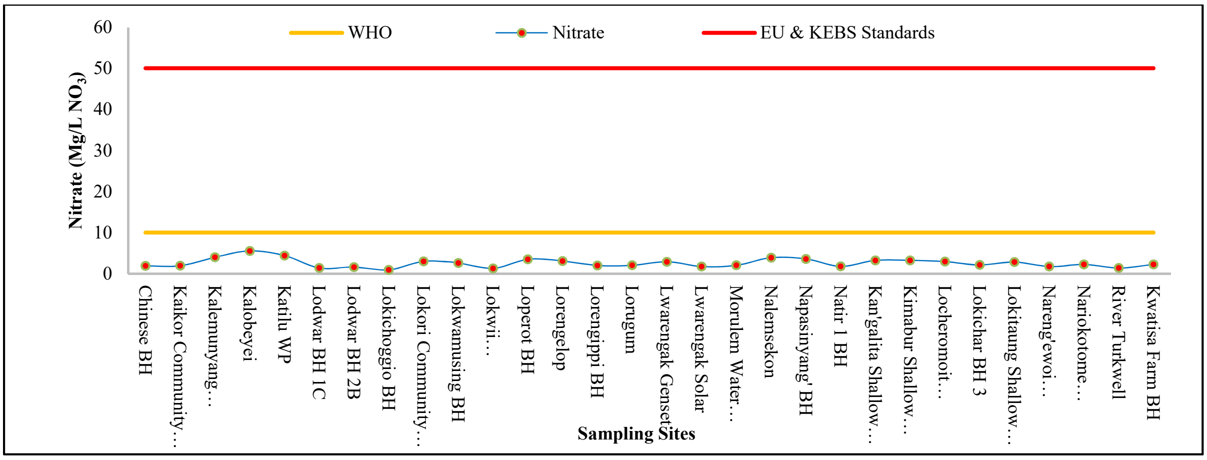

Fig. 19. Nitrate levels in the water samples (2013)

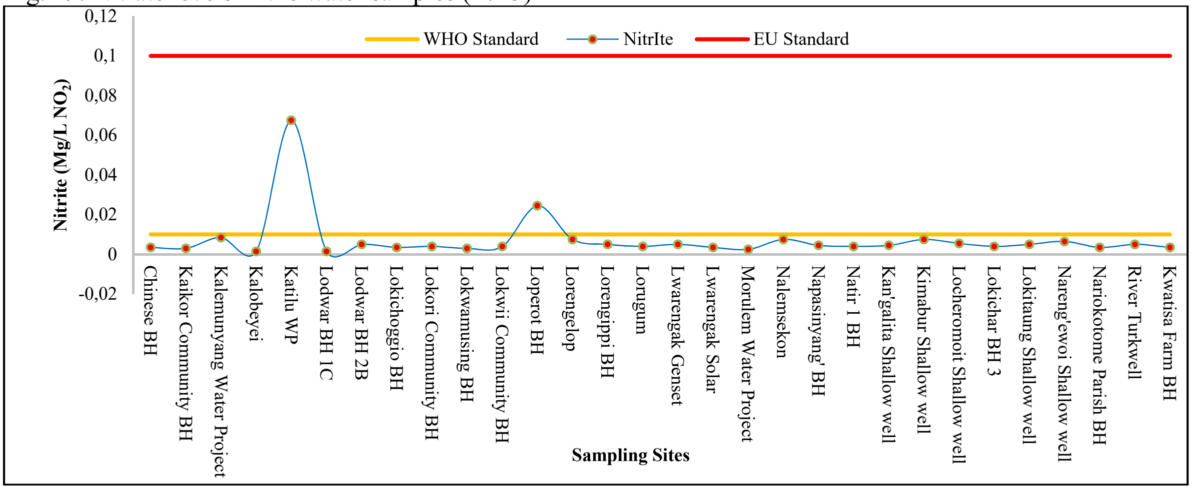

Fig. 20: Nitrate levels in water samples.

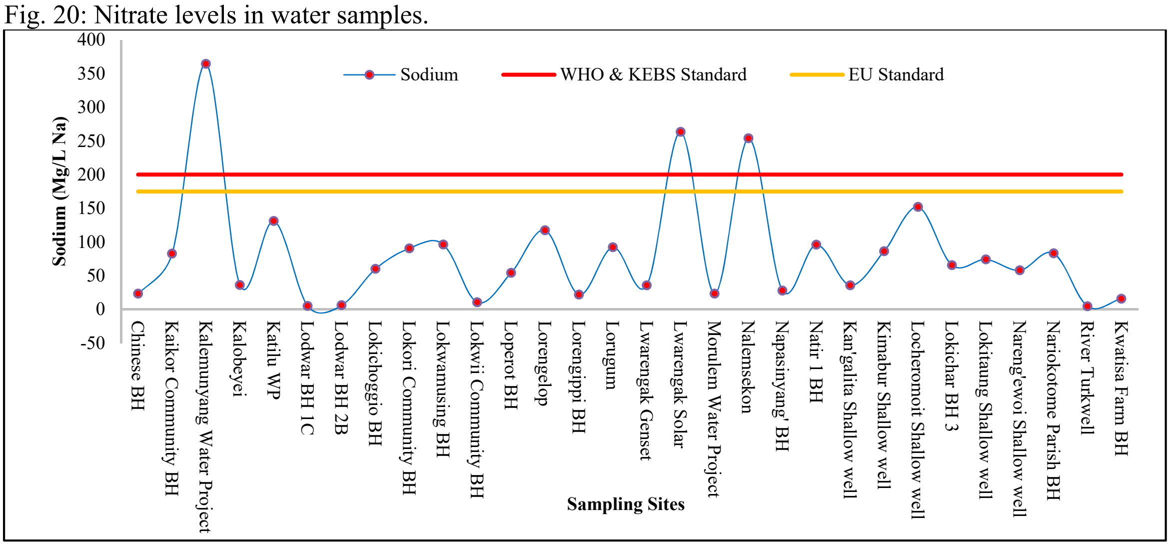

Fig. 21. Sodium levels in the water samples (2013)

## Conclusion

The water demand in Turkana is high around urban centres and that is where more boreholes are located. The aquifer is mainly a shallow aquifer which is mainly saline. The physical chemical parameters TDS, EC and chloride levels especially in Kalemunyang, Katilu and Lokitaung were above the recommended standards indicating that the Turkana groundwater is majorly saline. Kumar and Riyazuddin (2012) attribute this to shallow alluvial aquifers where sampling is done in a relatively oxic environment. ESIA report (2020) also notes that occasional exceedances of the chloride standard were observed in their sampled wells. According to research by Tanui et al, (2020) salinity is prevalent in the shallow Turkana grit and with is dominated by Ca–$HCO_3$ water type and Na–Cl water type. Fairly high fluoride levels that ranged between 0.5 to 1.5 mg/l were observed. And their effects were evident as skeletal fluorosis is quite prevalent in Turkana County. The high fluoride levels could be attributed to the geological formation of high volcanic rocks that have high fluoride ions that largely prevalent in the study region. Sodium cations were also highly prevalent is contributing towards the salinity.

It is expected that oil prospecting and drilling activities which started around 2012 (e.g. at the Ngamia-1 exploration well) may have a significant impact on water quality in the southern region of Turkana County. However, more research work is needed to determine the relationship between oil drilling and water quality by specifically providing site-specific evidence. Such a relationship is based on the fact that oil drilling activities can have an impact on ground rock structures. Also, the social-economic activities associated with oil prospecting such as the growth of urban centres and increase in population can also contribute to changes in the quality and quantity of groundwater.

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**References**

Asokan, S. M., Obando, J., Kwena, B. F., Luwesi, C. N. (2020). *Climate change adaptation through sustainable water resources management in Kenya: Challenges and opportunities.* African Handbook of Climate Change Adaptation, 1-11.

Feitelson, E., Tubi, A. (2017). A main driver or an intermediate variable? Climate change, water and security in the Middle East. *Global Environmental Change*, 39-48. doi:10.1016/J.GLOENVCHA.2017.03.00

JICA. (2013). *The Project on the Development of the National Water Master Plan 2030.* The Republic of Kenya: Nippon Koei Co Ltd.

Kang, H., Kim, K. S., Park, Y. S., Kim, N., Ok, Y. S., Kim, J., . . . Lim, K. J. (2009). Development and Application of SATEEC L Module for Slope Length Adjustment Based on Topography Change. *Korean Journal of Environmental Agriculture, 28*(2), 113-124.

KNBS/SID. (2014). *'Exploring Kenya's Inequality: Pulling Apart or Pooling Together?* Nairobi: KNBS.

Kumar, A., Riyazuddin, P. (2012). Seasonal variation of redox species and redox potentials in shallow groundwater: a comparison of measured and calculated redox potentials. . *Journal of Hydrology*, 444, 187-198.

Lapworth, D., Nkhuwa, D., Okotto-Okotto, J., Pedley, S., Stuart, M., Tijani, M., Wright, J. (2017). Urban groundwater quality in sub-Saharan Africa: current status and implications for water security and public health. *Hydrogeology Journal*, 25(4), 1093.

MacDonald, A. M., Lark, R. M., Taylor, R. G., Abiye, T., Fallas, H. C., Favreau, G., . . . West, C. (2021). Mapping Groundwater Recharge in Africa from Ground Observations and Implications for Water Security. *Environmental Research Letter, 16*(3). doi:org/10.1088/1748-9326/abd661

Maxwell, O. C., Olago, O. D., Odira, M. P. (2020). Water Availability Analysis of Multiple Source Groundwater Supply Systems in Water Stressed Urban Centers: Case of Lodwar municipality, Kenya. *Journal of Civil & Environmental Engineering*, 114.

Naderi, M. (2020). Assessment of Water Security under Climate Change for the large Watershed of Dorudzan Dam in Southern Iran. *Hydrogeology Journal, 28*, 1553–1574. doi:10.1007/s10040-020-02159-1

Ndegwa, G. M., Kiiru, I. (2010). Investigations on soil and water quality as affected by irrigation in turkana district, Kenya. . *Journal of Agriculture, Science and Technology*, 12(1), 11-31.

Oduor, A. R., Mutune, J., Malesu, M., Cherogony, K., Karuma, A., Cherogony, M., Onyango, D. (2012). *Food Security Master Plan for Turkana County.* Lodwar: Diocese of Lodwar.

Rusiniak, P., Kmiecik, E., Wątor, K., Duda, R., Bugno, R. (2021). Pharmaceuticals and personal care products in the urban groundwater–preliminary monitoring (case study: Kraków, Southern Poland. *Urban Water Journal*, 18(5), 364-374.

Swarzenski, W. V., Mundorff, M. J. (1977). *Geohydrology of North eastern province, Kenya (No. 1757-N).* US Govt. Print. Off.,.

Tanui, F., Olago, D., Dulo, S., Ouma, G., Kuria, Z. (2020). Hydrogeochemistry of a strategic alluvial aquifer system in a semi-arid setting and its implications for potable urban water supply: The Lodwar Alluvial Aquifer System (LAAS). *Groundwater for Sustainable Development*, 11, 100451.

The Netherlands Development Organisation (SNV). (2014). *The SNV Field report.* The Hague: SNV.

Ülker, D., Ergüven, O., Gazioğlu, C. (2018). Socio-economic impacts in a Changing Climate: Case Study Syria. *International Journal of Environment and Geoinformatics,* 5(1), 84-93. doi.org/10.30897/ijegeo.406273