© 2017 IJSRSET | Volume 3 | Issue 6 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Drinking Water Quality Challenges in Nakuru County, Kenya

Vincent O. Madadi, Mary W. Ngotho, Florence A. Masese
Department of Chemistry, School of Physical Sciences, College of Biological and Physical Sciences, University of Nairobi, P.O. Box 30197-00100, Nairobi, Kenya

ABSTRACT

Adequate quantity of safe drinking water is necessary for human health and development. However increasing population coupled with high demand of water for agriculture, households and industrial uses and power generation have led to declining quantity and quality of the life essential commodity. Nakuru is the fourth largest town in Kenya, located 160 kilometres northwest of Nairobi, and is one of the Kenyan towns that are seriously impacted by limited availability of water, leading to frequent water rationing. This study investigated the quality of the main drinking water sources of Nakuru town namely tap water, boreholes and Njoro River. We analysed physico-chemical parameters including pH, TDS, TSS and Electrical conductivity; heavy metals such as Pb, Mn, Cd, Cr and microbiological contaminants *E. coli* and total coliforms. We collected water samples from eight different sources and analysed them following standard methods. The results showed variation in the concentrations of different parameters across the sources. The mean Electrical conductivity varied from 169.2 -2,169.5 µS/cm, TDS from 84.66-1,082.5 mg/l, pH from 7.80-8.55, TSS from 27.5-93.5 mg/l, *E. Coli* from 0-233 CFU/ml and Total coliforms from 1-343 CFU/ml. Lead is the only heavy metal that was detected in significant amounts in water with concentration varying from bdl-0.057 mg/l. Except for pH and TSS, most of the parameters were above the WHO maximum guidelines for drinking water and the Kenya National Environment Management Authority (NEMA) guidelines. The results suggest that apart from the tap water, the ground and surface water of Nakuru was not safe for direct human consumption and therefore proper pre-treatment must be undertaken.

Keywords: Nakuru County, surface and groundwater quality, Heavy metals & Biological contamination.

I. INTRODUCTION

Water is one of the most essential commodities for human life and one of the key drivers in socioeconomic development and food security.[1,2] Lack of adequate and safe drinking water is suspected to be a cause of many human illnesses. However, due to expansion of industrial and agricultural activities, both surface and ground water sources are becoming increasingly contaminated by industrial and agrochemicals.[4,5,6,7,8,9,10] In addition increasing changes in land cover and use are also affecting the hydrologic responses in terms of surface discharge and ground water research.[11] The major concern is, therefore, to provide adequate quantities of drinking water that is free from chemical and biological pollutants.

Kenya for many years has been considered as a water-scarce country[12] with less than 647 cubic meter per capita of renewable freshwater supply compared to the international benchmark of 1000 cubic meters per capita.[13,14]

The country experiences bimodal rainfall pattern with the long rains starting from March to May while the short rains run from October to November. During the wet seasons, rain is the main source of drinking water and accounts for up to about 52% of the total drinking water supply especially in the rural areas. In dry season, however, the rural population relay on the natural sources of water which include: springs, rivers and streams for drinking and household use.[12] On the other hand, whereas the urban households have piped water into their residences or from public taps, majority of the residents of informal settlements do not have access to treated piped water, hence majorly rely on water vendors.

Various studies elsewhere have shown that ground water can be exposed to pollution due to geological conditions or anthropogenic sources which include leachate from dumpsites or waste disposal activities. In a study in Kwale[15] collected a total of 195 samples from fourteen villages during dry season and analyzed for physical-chemical parameters. The result showed that groundwater in the sampling area was alkaline with the pH out of the standard range (6.5-8.5). Heavy metals such as Pb, Cd and Mn were detected above the WHO limit of 0.01 mg/L.[16,17]

In a study to assess the relationship between chemical and microbial contamination of ground water sources and potential hazards in two peri- urban areas of Kisumu, Kenya, where shallow wells and pit latrines are widely used, 263 samples were collected from 61 groundwater sources for analysis of thermo-tolerant coliforms and chemical contaminants found that 10 out of 18 samples had nitrates above WHO guidelines, and 236 out of 263 were positive for thermo-tolerant coliforms, and the levels of fluorides in all samples were above the WHO guidelines of 1.5 mg/L.[17]

Further studies to assess sanitation practices among the residents of Kenyan urban slums and fecal contamination of domestic water sources which sampled 192 respondents from Langas slum and collected forty water samples showed that the main sources of domestic water was highly contaminated with fecal coliforms.[18] Further studies in Kisumu City to determine the level of faecal contamination in domestic water sources and to evaluate the potential contribution to intestinal helminthiases using membrane filtration technic to enumerate the total and faecal coliforms bacteria found that out of the 80 samples 75 (95%) were highly contaminated with *E. coli.* Suggesting that untreated well water is not suitable for human consumption.[19]

In Nigeria, a study conducted on seventeen boreholes and eight hand-dug wells from three different locations found that all the 3 locations had mild to high iron concentration (0.01-0.9 mgl^{-1}) and a mild to high acidity (4.47-6.95 mg/l). The contamination was attributed to the presence of dumpsites as potential source of pollution to the ground water because of high water table.[20] Further study on drinking water from borehole and tap water in Maiduguri found that some of the boreholes had pH falling out of the allowed range of (6.5-8.5), the concentration of some metals such as Cr and Cd was also above the WHO guidelines of 0.003 mg/l in all the samples.[21,22] In the North-east of Abuja federal capital city of Nigeria, to determine the water quality of Masaka, a peri-urban settlement also found water contamination by metals.[24] In the assessment conducted to determine the presence of biological contaminants in stored borehole water, *E. Coli.* was detected in water that had originally tested free of *E. Coli*. suggesting potential contamination during handling and storage.[23] In India, conducted to determine the quality of ground water from 47 boreholes in an area of 154 km^2 revealed that the ground water, in many places, was contaminated by high concentrations of NO_3, Cl, PO_4 and Fe.[24]

At regional and international levels, studies on spring water in Katwe and Kisenyi parishes in Uganda to examine bacteriology quality of spring water found that all the samples had the faecal count exceeding the WHO guidelines, while sixty percent of the samples had nitrate levels above the WHO guidelines.[25] The main objective of this study was to determine the quality of drinking water from various sources in Nakuru town.

II. MATERIAL AND METHODS

A. Study Area

Nakuru is the fourth largest town in Kenya and its located 160 kilometers northwest of Nairobi,[26] along the Kenya-Uganda highway, at an altitude of 1,800 m. The town experiences acute water shortage due tremendous increase in its population over the past three decades. For instance the population grew from 57,000 in 1957 to approximately 400,000 in 2017.[27,28] This has led to an increase in demand for basic services and infrastructure including housing, water and sanitation and roads, among many others. This in turn puts pressure on the limited resources, and to the county government to meet the needs of the town’s inhabitants. However, data on water quality is limited in the region since chemicals are perceived to be at low concentrations, although they may pose a potential threat to human health. This motivated our study to determine the extent of contamination by heavy metals, microbiological and physical parameters.

Water samples were collected from 8 different sites within Nakuru area. These included: Boreholes 1, 2, 3, 4, 5 and 6, NJoro River and Tap water as shown in Figure 1.

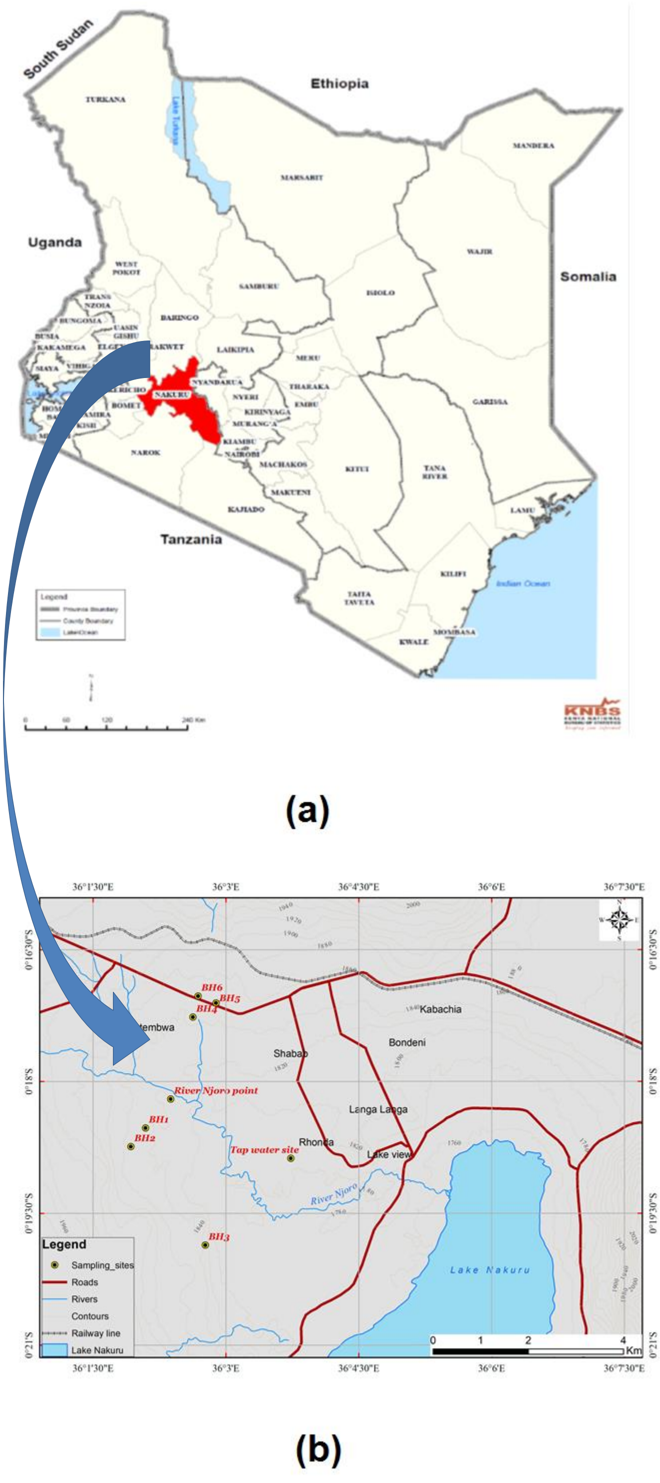

Figure 1. Study area (a) Map of Kenya showing location of Nakuru County[27,28] (b) Location of sampling sites.

Sample collection was done during the wet season in November 2013. Sample were collected by grab method in 1 L liter High Density Polyethylene (HDPE) plastic bottles pre-cleaned with distilled distilled water. Water samples were preserved in cooler boxes and transported to the laboratory where they were stored at 4 ^{o}C. Nitric acid was added to preserve samples for heavy metal analysis.

B. Test for presence of E. Coli:

1 ml of the raw water sample was transferred onto the 3M E. coli petri-film test plate, in duplicate. The petrifilms were incubated at 37 $^{\circ}$C for 24 hours. After incubation blue colonies were counted and recorded representing E. coli. The red colonies indicated the presence of other coliforms, whereas the sum of the two provided the number of total coliforms in the water per milliliter of water.

C. Determination of pH

The pH meter model IQ science instruments was used for pH determinations. The meter was calibrated using buffer solutions of pH 7.0 and 4.0. After calibration, 100 ml of the sample was transferred into a beaker. pH electrode was dipped into the sample and stirred to achieve homogeneity. The final stable reading was recorded as the pH of water. The above procedure was repeated for all samples in duplicates.

D. Electrical Conductivity and Total Dissolved Solids:

Hanna instrument TDS/Conductivity meter was used to measure TDS and EC. The meter was calibrated using standard solutions of 1,413 µS/cm. After calibration, the conductivity of the samples was measured by dipping the probe into the samples and recording the stable reading. The same procedure was repeated for TDS.

E. Total Suspended Solids (TSS):

TSS was measured by gravimetric method. Whatman no. 42 filter papers were dried in an oven at 105^{o}C for 2 hours, cooled in a desiccator and weighed. The weight was recorded and the above procedure was repeated until a constant weight was obtained. 100 ml of well mixed water was taken and filtered through the weighed filter paper. The filter papers were dried in an oven at 105 ^{o}C for 2 hours, cooled and weighed again. The difference between the weighed filter paper before filtration and after the filtration was used to calculate the total suspended solids
using the formula:

$$TSS\ (mg/L) = (W2-W1)\ x10^{6}/100$$

Where W1 = Weight of the dried paper before filtration (g), W2 = weight of dried paper after filtration (g), and 100 is the volume of water filtered (ml).

F. Total Solids TS:

200 ml glass bottles were thoroughly cleaned, rinsed with distilled water and dried in an oven at 105 ^{o}C until all the moisture was removed. The bottles were cooled in a desiccator and weighed. 100 ml of each raw sample was transferred into the weighed beaker and dried in an oven at 105 ^{o}C for 24 hours. The bottles were then cooled in a desiccator and their weights taken. The difference in weight was was used to calculate TS as shown below:

TS (mg/L) = (W2-W1) x10^6/100

Where, W1 = Weight of the dried bottle before filtration (g), W2 = weight of bottle after filtration (g), and 100 is the total volume of water taken (ml).

G. Heavy metal analysis:

100 ml of each sample was measured into a clean 250 ml conical flask, 3 ml of concentrated Nitric acid (HNO_3) was added to each flask. The flasks were placed on a hot plate and boiled to less than 5 ml. The mixture was cooled, then 5 ml concentrated HNO_3 was added. Each flask was covered with a watch glass, returned to the hot plate and gently refluxed. The mixture was further heated while additional acid was added as necessary until completion of digestion. The final solution was evaporated to less than 5 ml and cooled. 10 ml Nitric acid and HCL mixture (1:1) was added followed by 15 ml water. The solution was then heated for 15 minutes to dissolve any precipitate or residues. The digests were cooled and filtered into 100 ml volumetric flask to remove any insoluble material that could clog the nebulizer. The final volume was made up to the 100 ml volume mark using distilled water.

Heavy metals concentrations were determined using Atomic Absorption Spectrometer. In addition to calibration using metal salts, quality checks were also performed on the instrument by checking the absorbance after every 5 samples.

III. RESULTS AND DISCUSSION

A. *E. coli* present conformation test:

Table 1 shows the summary of results of bacteriological contaminants measured in drinking water from Nakuru County. E. coli was detected in most of the water samples during the study except for the tap water, Boreholes 1 and 5 water. Other coliforms were detected in all samples except Borehole 6. The results suggest high prevalence of bacteriological contamination of drinking water sources in Nakuru County.

Comparison of bacteriological contamination in different water sources revealed that E. coli was highest in River Njoro water followed by Boreholes 2,3,4 and 6 Figure 2. The average concentration of E. coli in the river samples was 233 CFU/ml, whereas WHO Maximum limit for E.coli concentration in drinking water is 0 CFU/100 ml. Most of the water sources did not meet the WHO cretaria for drinking water quality. Since the study was done during wet season, the results could also suggest the potential influx of bacteriological contaminants from residential and grazing land into the river, by runoff.

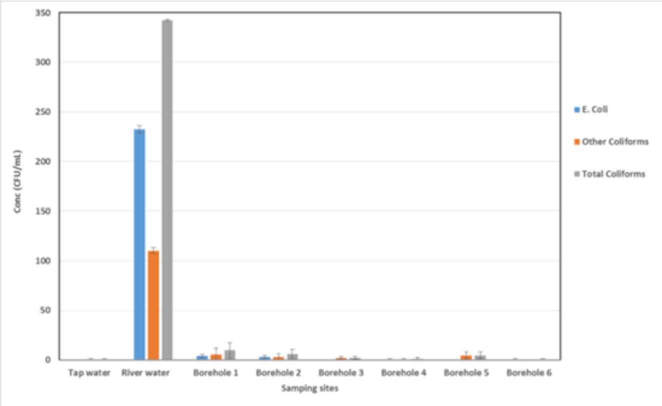

Figure 2. Comparison of E. coli and other coliforms level in different water sources.

In addition, poor hygienic conditions like washing of cloths, watering animals and cleaning of vegetables directly into the river could have also contributed to the high E. Coli load detected in the river water.

B. Physico-Chemical parameters:

i) Water pH:

Most of the samples had pH within the WHO guideline of 6.5-8.5 as shown in Table 1 below. Tap water had the lowest pH at 7.55, whereas water from Borehole 1 had the highest pH at 8.56, which was slightly above the highest WHO guideline limit.

ii) Total Dissolved Solids (TDS) and Electrical Conductivity (EC)

The mean electrical conductivity of the water samples ranged from 411.00 μScm^{-1}- 2,169.50 μScm^{-1}. Four sites recorded EC values below 500 μScm^{-1}. However, samples from Boreholes 6, 5 and 4 had the highest EC with mean concentrations of 2,169.50, 1755.50 and 1,770.50 μScm^{-1}, respectively, which were also above the WHO guideline of 1,000.00 μScm^{-1}. Electrical conductivity is a measure of water's ability to conduct electric current and is associated with amount of dissolved salts in the water and the total amount of mobile charged ions. Whereas EC and TDS do not give an indication of the specific elements present, but they are good indicators of the presence ionic contaminants such as sodium, potassium or sulphates and other salts in water. For both EC and TDS in water samples, the trend in concentration was River water< Tap water< Borehole water.

Table 1. Concentration of physico-chemical parameters

	pH	EC (µS/cm)	TDS (mg/l)	TSS (mg/l)
Tap water	7.55±0.01	411±8.49	206.00±2.83	9.35±0.21
River water	7.77±0.03	169.20±3.11	84.55±1.48	51.50±2.12
Borehole 1	8.56±0.01	885.00±12.73	442.00±8.48	36.5±2.10
Borehole 2	8.05±0.01	496.00±2.83	247.50±0.71	77.0±2.80
Borehole 3	8.01±0.02	454.50±2.12	227.50±0.71	55.5±0.70
Borehole 4	8.11±0.04	1,770.50±13.43	884.00±2.82	35.5±2.00
Borehole 5	8.14±0.00	1,755.50±3.54	877.50±3.53	27.5±2.10
Borehole 6	8.36±0.01	2,169.50±9.19	1,082.50±3.54	32.0±4.20

The highest concentrations of TDS were measured in water from borehole 6, 5 and 4 whereas the lowest values were recorded in water from River Njoro and the tap water. The concentration of TDS in water from Boreholes 4, 5 and 6 were all above the WHO maximum permissible limits of 500 mg/L.

iii) Total Suspended Solids (TSS)

The concentrations of total suspended solids varied from 0.94 to 7.70 mg/L. Generally the TSS levels in water were low suggesting no significant anthropogenic effect on the source waters during the sampling period (Table 1). The trend in TSS concentration in water varied from Tap water< River water< Borehole water.

C. Heavy metal concentrations in water:

The heavy metals investigated in the study were: cadmium (Cd), manganese (Mn), lead (Pb) and chromium (Cr). The presence of heavy metals was tested using Atomic Absorption spectra-10. Figure 3 shows the sample calibration curve of lead. Good linearity (R^2 = 1) was achieved between the instrument response and concentration of the standards.

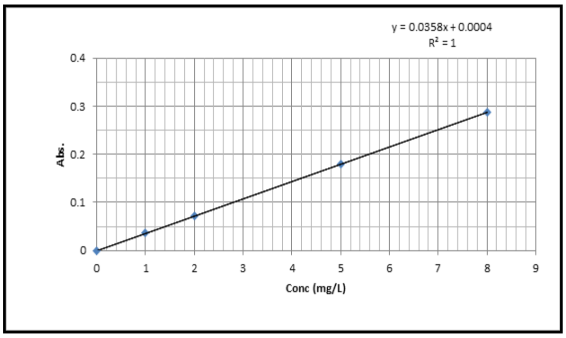

Figure 3. Sample calibration curve of lead

Pb was the only heavy metal detected in in water samples as shown in Table 2, whereas the concentration of Mn, Cd and Cr were all below the detection limit. The highest concentration of lead was measured in the river water, followed by Boreholes 4 and 5. Potential sources of lead into the river water could be runoff from households and industrial activities. Poor disposal of lead batteries and previous use of leaded gasoline could also form potential sources of lead in the river water. However, the concentration of lead was above WHO maximum permissible level of 0.01 mg/L[16] for all the samples suggesting a widespread contamination issue.

Table 2. Concentration of heavy metals in water mg/L

	Cd	Mn	Pb	Cr
Tap water	bdl	bdl	bdl	bdl
River water	bdl	bdl	0.057±0.008	bdl
Borehole 1	bdl	bdl	0.028±0.003	bdl
Borehole 2	bdl	bdl	0.035±0.004	bdl
Borehole 3	bdl	bdl	0.037±0.008	bdl
Borehole 4	bdl	bdl	0.052±0.003	bdl
Borehole 5	bdl	bdl	0.051±0.015	bdl
Borehole 6	bdl	bdl	0.014±0.004	bdl

D. Discussion:

The study revealed that Nakuru water is contaminated with different amounts of chemical and bacteriological contaminants. Except the tap water, the concentration of lead was above the WHO maximum limit for drinking water for the rest of the samples raising concern due to health risks associated with the heavy metal. Continued consumption of such water without further treatment could lead to bioaccumulation of lead in the body. Lead is known to cause various toxicity effects to the body such as; high blood pressure, kidney dysfunction, memory loss anemia, mental retardation in children among others. Biological contaminants were also widely detected in the source waters except the tap water. This widespread occurrence of microbial and chemical contaminants could be associated with sanitation challenges that need to be addressed.[29] Previous studies have also reported water contamination in the region especially fluorides.[30]

IV. CONCLUSION

Most of the physico-chemical parameters analyzed were below the WHO guidelines apart from EC and TDS confirming possible presence of other ions in source waters, thus not completely safe for drinking. Other than lead all other metals analyzed were below detection limit. However, the concentration of Pb in tap water was below WHO standards of 0.01 mg/l. Accumulation of lead in the human body lead to toxic effects thus this pose a possible threat to human health & the environment. River water registered the highest level for E. coli and other coliforms this could be due to runoff from household and agriculture activities which contain high load of organic matter contaminate the water. Ground water contamination in some of the sites since they recorded significant values of E. coli.

V. REFERENCES

[1]. Munir A. Hanjra, M. Ejaz Qureshi (2010) Global water crisis and future food security in an era of climate change. Food Policy, 35: 365–377.

[2]. Srinivasan, V., E. F. Lambin, S. M. Gorelick, B. H. Thompson, and S. Rozelle, (2012), The nature and causes of the global water crisis: Syndromes from a meta-analysis of coupled human-water studies, Water Resour. Res., 48: 1-16.

[3]. Tyagi, O.D, Mehra M., (2000) A Textbook of Environmental Chemistry, First Edition, Anmol Publishers, New Delhi, India.pp.70-90.

[4]. Madadi O.V., (2017) Occurrence and Distribution of Organochlorine Pesticide Residues in Water and Soil Samples from Kargi Area, Marsabit County, Kenya. IJSRSET 3(5):91-99.

[5]. Abong'o, A.D., Wandiga,S.O., Jumba,I.O., Madadi,O.V. and Kylin,H., (2014) Impacts of Pesticides on Human Health and Environment in the River Nyando Catchment, Kenya. Best: International Journal of Humanities, Arts, Medicine and Sciences. 2(3): 1-14.

[6]. Osoro EM, Wandiga S.O, Abongo DA, Madadi V O and Macharia J W. (2016) Organochlorine Pesticides Residues in Water and Sediment from Rusinga Island, Lake Victoria, Kenya. IOSR-JAC. 9 (9): 56-63. EISSN: 2278-5736.

[7]. Madadi, O.V., Wandiga, O.S., Ndunda N.E. and Mavuti, K.M., (2017) Analysis of Organochlorine Pesticides in Lake Naivasha Catchment. IJSRSET, 3(5): 139-145.

[8]. Okworo, K.E., Madadi, O.V., Abong'o, A.D., Ochieng,A.A., (2017) Assessment of the Level of Organochlorine Pesticides Contamination in Kales, Water and Soil from Naivasha, Kenya. International Journal of Scientific Research in Science, Engineering and Technology. 3(5): 205-213.

[9]. Ondiere, B.V., Madadi O. V., Ochieng.A.A. and Oduor,F.D.O., (2017) Assessment of Heavy Metals Contamination in Lake Elementaita Drainage Basin, Kenya. International Journal of Scientific Research in Science, Engineering and Technology. 3(5): 283-289. Print ISSN: 2395-1990. Online ISSN: 2394-4099

[10]. Naziriwo B.B., Wandiga, S.O., Madadi,O.V. and Abong'o A.D., (2009) Physicochemical parameters and magnetic speciation of Iron in Nakivubo Channel and Lake Victoria waters.

Lakes and Reservoirs: Research and Management, 14: 127-137.
[11]. Tracy J. Baker and Scott N. Miller, (2013)Using the Soil and Water Assessment Tool (SWAT) to assess land use impact on water resources in an East African watershed. Journal of Hydrology, 486: 100–111.
[12]. Josephine K. W Ngaira, (2009) Challenges of water resource management and food production in a changing climate in Kenya. Journal of Geography and Regional Planning. 2(4): 097-103.
[13]. George M. Ogendi and Isaac M. Ong'oa, (2009) Water Policy, Accessibility and Water Ethics in Kenya, 7 Santa Clara J. Int'l. 7(1): 177.-196. Available at: http://digitalcommons.law.scu.edu/scujil/vol7/iss1/3
[14]. UNESCO World Water Assessment Programme, (2006) Kenya National Water Development Report (UN-WATER/WWAP/2006/12 2006).
[15]. Chege, M.W., Hashim, N.O. and Merenga, A.S., (2013) Physio-chemical analysis of ground water in Gazi-Mrima Hill Region of Kwale county, Kenya, J.Physical department, Kenyatta University.
[16]. WHO, (2017) Guidelines for drinking-water quality: fourth edition incorporating the first addendum ISBN 978-92-4-154995-0. Available online: http://apps.who.int/iris/bitstream/10665/254637/1/9789241549950-eng.pdf?ua=1
[17]. WHO, (2011) Guidelines for Drinking-water Quality. 4th edn. Avaialable online: http://apps.who.int/iris/bitstream/10665/44584/1/9789241548151_eng.pdf.
[18]. Wright, J., Cronin, A., Okotto-Okotto, J., Yang, H., Pedley, S., Gundry, S.W., (2013) A spatial analysis of pit latrine density and groundwater source contamination. Environ Monit Assess. 185(5):4261–4272.
[19]. Kimani-Murage, E.W. and Ngindu A.M., (2007) Quality of Water the Slum Dwellers Use: The Case of a Kenyan Slum, J. Urban Health, 86, (6): 829-838.
[20]. Opisa S., Odiere M.R., Jura, W.G., Karanja DM, Mwinzi PN., (2012) Faecal contamination of public water sources in informal settlements of Kisumu City, western Kenya, water sci technol 66(12):2674-81.
[21]. Akudo,EO.,Ozulu,GU.,Osogbue,LC., (2010)Quality Assessment of ground water in selected waste dumpsite ares in Warri, Nigeria. Environmental Research journal, 4: 281– 285.
[22]. Babagana, K., Jibrian, M. D. and I.I. Ndakawa, (2009) Elemental Analysis of Tap water and Borehole water in Maiduguri Semi Arid Region, Nigeria. European Journal of Applied Science 1(2): 26-99.
[23]. Muhammad, M. A. and Fanan, U., (2011) An Assessment of ground water quality for drinking from hand-dug wells in masaka, Nigeria, J.bayero University of association and management studies 14,(1):79-95.
[24]. Jeevanandam, M ., R. Kannan, S. Srinivasalu and V. Rammohan, (2007) Hydrogeochemistry and groundwater quality assessment of lower part of the Ponnaiyar River Basin, Cuddalore district, South India. Environmental monitoring and assessment, 132 (1): 263-274.
[25]. Haruna, R., F. Ejobi, E.K. Kabagambe, (2005) The quality of water from protected springs in Katwe and Kisenyi parishes, Kampala city, Uganda. African Health Sciences, 5(1): 14-21.
[26]. Ojwando, O.K. and B.M. Mutua, (2015) Trace Elements in Rainfall Collected around Menengai Area Kenya. Proceedings World Geothermal Congress, 19-25 April 2015. Melbourne, Australia.
[27]. Kenya National Bureau of Statistics (2013) Economic Survey. KNBS, Nairobi. Kenya.
[28]. GoK, (2013) First County Integrated Development Plan (2013-2017). County Government of Nakuru. Avaialable online at: http://Www.Nakuru.Go.Ke/Wp-Content/Uploads/2014/03/Nakuru-County-Intergrated-Dev-Plan-2013-2017.pdf
[29]. Ali,F. A. and R. J. Young, (2014) An assessment of groundwater contamination around a solid waste disposal site in Kano, Nigeria. WIT Transactions on Ecology and The Environment, 180:317-323. www.witpress.com, ISSN 1743-3541.
[30]. Wambu, E.W. and G.K. Muthakia, (2011) High Fluoride Water in the Gilgil Area of Nakuru County, Kenya. Research report Fluoride. The International Society for Fluoride Research. 44(1): 37–41.