Original Research Article

Assessment of Water Quality in Pangani, Kayole and Dandora Boreholes in Nairobi County, Kenya

ABSTRACT

This study was done to assess the physical-chemical properties of some boreholes in Pangani, Dandora and Kayole in Nairobi County, to assess the content of some heavy metals in some boreholes in Pangani, Dandora and Kayole and to determine the bacteriological quality of the water. These were checked for compliance as per the World Health Organization's guideline values. Borehole water samples were collected from Dandora, Kayole and Pangani. Water parameters determined included electrical conductivity, total suspended solids, total dissolved solids, pH, fluoride, chloride, ammonia, nitrate, *Escherichia-coli* total count and analysis of some selected heavy metal ions. The measurements of pH, fluoride, and electrical conductivity were made by an ion-selective electrode. The determinations of total dissolved solids and total suspended solids were made by the gravimetric method. The titration method was used to quantify chloride, while ultraviolet-visible spectrophotometer was used to measure ammonia and nitrate. *E. coli* and total counts were ascertained by the biological method. Heavy metals were measured using atomic absorption spectrophotometer. All boreholes met the guideline values of WHO with regard to pH, electical conductivity, total dissolved solids, chloride, and ammonia. Total suspended solids were found to be above the recommended limits of WHO. Nitrate values in all the borehole sites conformed to the WHO guidelines except at site Pangani Borehole 1. *Escherichia coli* conformed to WHO guideline except at Pangani Borehole 2. Total coliforms for did not conform to the set limit values. The concentration of zinc conformed with the set limit values except that of Pangani Borehole 1, Pangani Borehole 2 and Pangani Borehole 3. Concentrations of lead, copper and cadmium did not conform to the WHO guideline limit values.

Keywords: Physical-chemical, boreholes, heavy metals, bacteriological

1. INTRODUCTION

Water is vital in sustaining life in humans and other living organisms. Water as a universal solvent helps the cells to transport oxygen and other nutrients needed by the body in humans. Many chemical reactions in the body requires the presence of water in the building of larger molecules. The water for use by humans should meet certain standards as prescribed by various organizations like the World Health Organization [1]. The rapidly increasing population has put a lot of strain on governments to satisfy the demand for clean water [2].

According to Albert et al. [3], many countries across the globe are facing water shortages due to changes in climate and population growth. Water generally is not evenly distributed around the globe to satisfy the ever-increasing demand [4]. According to the World Health Organization guidelines, water suitable for drinking should not possess significant contaminants that can endanger the human health. The most susceptible groups to waterborne illness include young children and the elderly.

Research conducted by Bremmer et al. [5] showed that about 43% of Kenyans lack access to clean and safe drinking water. In the rural areas of Kenya and in some of the urban informal settlements, water scarcity has been experienced due to insufficient investment in water distribution. As a result, many of these people are affected by water-borne diseases. There is a substantial rural-urban disparity in terms of the availability of safe water. A report published by Marshall [6] showed that almost 85 % of urban settlers globally have no access to clean water.

It has been found from studies done that some sub-Counties in Nairobi County have experienced an acute water shortage which has made many households to rely on underground water sources (boreholes). This has helped to supplement the city's insufficient water supply as studied by Ochungo et al. [7]. In a past study done by Nkonge [8], he found that fluoride, iron and manganese were above the WHO recommended limit. In another study by Kiplagat et al [9], it was found that arsenic level in 16 % of the boreholes in the central region were found to be above the World Health Organizations's guideline value.
Assessment of the quality of water in these sub-Counties will therefore assist in mapping out the affected areas which will lead to setting out mitigation steps by the Nairobi County Government. Hence, there was a knowledge gap in relevant studies to ascertain the level of pollutants in the underground water.

2. MATERIAL AND METHODS

2..1 Study area and sampling points

The research was carried out in five regions of Nairobi County (Fig 1). The areas were located at Dandora (longitude E 36°53'30.1434" and latitude S 1°15'26.38692"), Pangani (longitude E 36°50'22.5006" and latitude S 1°16'4.5858") and Kayole (longitude E 36°54'19.62936" and latitude S 1°16'48.93888"). Water samples were collected in December 2021 from boreholes in

Dandora, Kayole and Pangani. The sampling sites are shown in Fig 1.

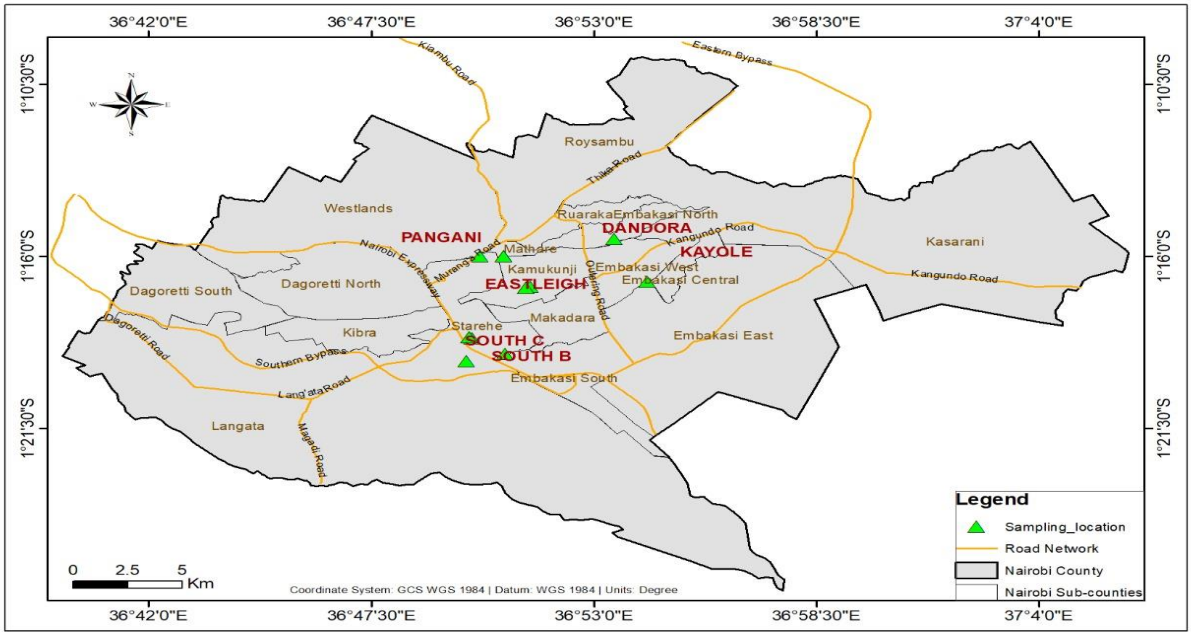

Fig 1: Location of the sampling points in the Nairobi County

The mapping of the various sites was done using Global Positioning System (GPS) to determine their spatial location and later used for GIS evaluation. Groundwater sampling was carried out in accordance with the groundwater sampling guidelines [10]. Water samples were collected from designated boreholes in triplicate using sterilized plastic bottles. The collected samples were transported in controlled conditions in cooler boxes to Chiromo Campus. These were stored in appropriate conditions while awaiting analysis. The depth of the boreholes at Dandora, Pangani, and Kayole ranged from 200-400 m ([11].

2.2 Coordinates of the sampling points in Nairobi County

Table1 shows various sampling points and their longitudes and latitudes.

Table 1: Sampling points with the corresponding GPS coordinates

Sampling point	Longitude	Latitude
Dandora	E 36°53'30.1434"	S 1°15'26.38692"
Kayole	E 36°54'19.62936"	S 1°16'48.93888"
Pangani	E 36°50'22.5006"	S 1°16'4.5858"

2.3 Chemicals used in analysis.

Potassium chromate, sodium chloride, silver nitrate, Nessler's reagent, sodium hydroxide, borate buffer, hydrochloric acid, ammonium chloride, phenol sulphonic acid, potassium nitrate,

ammonium hydroxide, nitric acid, CTDA (trans-1,2-diaminocyclohexane N,N,N′,N′-tetraacetic acid), sodium fluoride and glacial acetic acid were used in the analysis of water samples.

2.4 Apparatus and equipment used for analysis.

Atomic absorption spectrophotometer (AAS-6300, Shimadzu, Japan), EC/ pH /TDS multi-meter (model 15, Fisher Scientific), ultraviolet-visible spectrophotometer (UV-1700, Shimadzu, Japan), pH meter (model MI306), fluoride ion-selective electrode (SN. X28312), analytical balance (No.C12970), hot plate, burettes, beakers, volumetric flasks, conical flasks and no 4 filter paper.

2.5 Collection and storage of samples

In sampling water from each borehole, three 1-litre plastic bottles were first cleaned with soap and thereafter sterilized with distilled water. The plastic bottles were then filled to the brim and caped. The samples were then placed in a cooler box with ice for immediate delivery to the Department of chemistry laboratory, University of Nairobi. pH was determined on site.

2.6 Physical-chemical parameters determination

The physical-chemical parameters studied included total dissolved solids, total suspended solids, electrical conductivity, pH, fluoride, chloride ammonia and nitrate.

2.6.1Total dissolved solids (TDS)

Total dissolved solids determination was done through the gravimetric method. The beakers were cleaned and dried for one-hour at 105 °C before being placed in a desiccator to cool slowly before taking the weight of the cooled beakers. The process of drying was done three times until a constant weight of the coded beaker was achieved. Using a measuring cylinder, 100 ml of filtered sample was placed in the coded beaker, dried for 2 hours in an oven at 105°C to ensure all the water evaporated and then placed in a desiccator to cool. An analytical balance was used to weigh the beakers and the processes of drying were repeated to ensure a constant weight was achieved before determining the weight difference. The procedure was repeated for all water samples [12].

2.6.2 Total Suspended Solids (TSS)

A well-mixed sample (100 ml) was filtered through a weighted standard glass fiber filter and the residue retained on the filter was dried to a constant weight at 103-105°C. The increase in weight of the filter represented the total suspended solids. This was then converted to mg/L.

2.6.3 Determination of electrical conductivity and pH

At room temperature (25°C), the EC and pH meters were calibrated using different calibration standards and verified using known concentrations of solutions. In the calibration of pH, a Buffer solution of pH 4 and 10 were used. First the electrode was placed in the pH 10 buffer solution. After approximately one minute the measurement became stable. The electrode was then rinsed with deionized water. The electrode was then placed in the pH 4 buffer solution. These steps were then repeated until a reliable measurement was obtained. 20 mL of the borehole water was placed in a beaker and the pH electrode dipped into the sample. The reading was then taken.

In the electrical conductivity measurement calibration, the electrode was first placed in the 0.001 M KCl conductivity buffer solution. This buffer solution gave a conductivity value of 146.9 µS/cm. After approximately one minute the measurement was stable. This step was repeated until a

reliable measurement was obtained. 20 mL of the borehole water was placed in a beaker and the electrode placed in the sample. The reading was then taken. The pH/EC meter used was Hanna model 08655183.

2.6.4 Determination of fluoride

2.6.4.1Apparatus

An ion selective electrode for fluoride ion (Thermo Scientific-Orion Star Series) coupled with a reference electrode Ag/AgCl was used for fluoride measurements.

2.6.4.2 Chemicals, reagents and materials

Trans-1,2-diaminocyclohexane N,N,N′,N′-tetraacetic acid (CTDA), sodium chloride, sodium fluoride, sodium hydroxide and glacial acetic acid were of analytical reagent (AR) grade and were purchased from Merck (Germany).

2.6.4.3 Sampling

Water from each of the sampling points in triplicate for Boreholes were collected from selected areas of Nairobi County. These were then stored in a cooler box then transported to the Department of Chemistry laboratory. The samples were stored in plastic bottles made of polyethylene terephthalate [13].

2.6.4.4 Fluoride standards and analysis

A series of fluoride standards ranging from 0.1, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0 mg/L were prepared. These standards were prepared using sodium fluoride in deionized water. Total ionic strength adjusting buffer II (TISAB II) was prepared by mixing 4 g CDTA, 57 mL glacial acetic acid and 58 g NaCl in about 500 mL deionized water. The pH was adjusted to 5-5.5 by adding
A few drops of 5M NaOH (200 g/L) and then this was diluted to 1 Litre. This range of fluoride ion concentrations ensured that the ion meter was properly calibrated for the quantitative determination of fluoride in water samples.

2.6.4.5 Fluoride determination

A sample bottle was taken and 10 mL of the sample was taken and mixed with 10 mL of TISAB II; after that, fluoride concentrations of all the samples were determined in duplicate using fluoride ion selective electrode.

2.6.5 Determination of chloride

The chloride solution containing chromate was titrated with silver nitrate. Silver chromate precipitated and at the end point, red silver chromate was formed. The following reagents were made to determine chloride concentration:

2.6.5.1 Preparation of 0.25 M potassium chromate solution

1.0g of K_2CrO_4 was placed in a 20-mL volumetric flask. Distilled water was then added with shaking and the volume made to the mark. This then gave 5 % potassium chromate solution.

2.6.5.2 Preparation of 0.01 M sodium chloride

0.5843g of NaCl was taken and placed in a 100-ml volumetric flask. That was followed by topping up of solution with deionized water with shaking to the mark [14].

2.6.5.3 Standardization of $AgNO_3$ solution with 0.1M NaCl

16.987g of silver nitrate was put into a 500-ml volumetric flask. Deionized water was then added with shaking to the mark. Titration of 10 ml of sodium chloride solution with silver nitrate was done using a chromate indicator until the end point (red color). The process of titration was continued four times to ensure precision was achieved and the average titer was calculated.

2.6.5.4 Chloride concentration determination

25 mL of the sample was taken and placed into a porcelain dish. 1 mL of 0.25 M potassium chromate (5 % potassium chromate) was then added into the dish and titrated with standard silver nitrate solution until the slightest reddish colour (due to the excess formation of silver chromate) appeared [14].

2.6.6 Ammonia

The following reagents were prepared to determine the ammonia concentration in the borehole water samples: Nessler's reagent: 100 g HgI and 70 g KI were placed in a 1000-ml volume flask, and a small volume of distilled water was added to dissolve the solutes. A chilled solution of 160 g of NaOH diluted in 500 ml of filtered water in a 1-liter volumetric flask was progressively added to this. This was then diluted with distilled water to a liter and stored away from sunlight.

Borate Buffer: A measured volume of 0.1M sodium hydroxide solution (88 ml) was added to 0.5 liters of 0.025 M sodium tetraborate heptahydrate in a 1-liter volumetric flask (borate was made by weighing 9.5g of $Na_2B_4O_7.10H_2O$ dissolved and diluted with distilled water in a 1-litre volumetric flask and made up to the mark).

2.6.6. 1 Preparation of the sample

25 mL of distilled water was added to volumetric flask containing boiling chips (previously treated with diluted NaOH). After adjusting the pH to 9.5 with 0.1M NaOH. A few drops of 1.25M borate buffer was added, followed by 15 ml of distilled water for a period of 2 to 3 minutes, and finally 2.5 ml of 1M HCl was added. Because of the hydrochloric acid solution level, the condenser tip was extended. After diluting the distillate to 25 mL with distilled water, an aliquot was Nesslerized to estimate the concentration of ammonia in the sample.

2.6.6.2 Ammonium chloride stock solution preparation

2.9871 g of NH_4Cl was dissolved in distilled water and topped up to the mark in a 1-liter volumetric flask to create NH_4^+. Working standards were made with Nessler's reagent and serial dilutions were done. The absorbance data for the standards were measured. The samples were analyzed using a 425-nanometer ultraviolet-visible spectrophotometer.

2.6.7 Nitrate

The phenol-sulfonic acid technique was used to determine the nitrate ion in borehole and tanker water samples. Nitrate interacted with phenol sulfonic acid to generate a yellow nitro derivative in an alkaline solution. A change in the structure of the nitro derivative caused the yellow color. Beer's law states that the color intensity is directly proportional to the concentration of NO_3 in the water sample. The concentration of NO_3 was measured using a Ultraviolet-visible spectrophotometer [15].

2.6.7.1 Preparation of 1000 ppm potassium nitrate standard

3.5 g of potassium nitrate was weighed using an analytical balance and dried in a 105°C oven before being stored in a desiccator to cool. 1.65 g of potassium nitrate was dissolved in 10 mL of water before being diluted to 1000 mL to give 1000 ppm. Serial dilutions were performed using the dilution formula C1V1 =C2V2.

2.6.7.2 Preparation of 100 ppm of potassium nitrate stock solution.

10 ml of 1000 ppm potassium nitrate solution was taken and placed into a 100-ml volumetric flask. This was then made to volume with distilled water. This gave 100 ppm solution. 100 ppm stock solution was used to make 1 ppm, 2 ppm,4 ppm, 6 ppm and 8 ppm of potassium nitrate. 25ml of 1 ppm of potassium nitrate was added to a 100-ml beaker. 2ml of phenol sulphonic acid and 10ml of concentrated ammonium hydroxide were added to the beaker with stirring. Repeat preparations were done for 2 ppm ,4 ppm,6 ppm and 8 ppm. The samples were thereafter measured using a Ultraviolet-Visible spectrophotometer set at a wavelength of 410 nm.

2.6.7.3 Preparation of the sample

The sample was prepared by pipetting 25 ml of borehole water sample into a 150 ml beaker. 2 mL of phenol sulfonic acid was added, and 10 ml of concentrated ammonium hydroxide was also added with care. A blank was prepared by adding 25 ml of distilled water in a 15-ml beaker, 2ml of phenol sulphonic acid and 10ml of ammonium hydroxide were added. Ultraviolet-Visible was then used to measure the absorbance.

2.6.8 Determination of heavy metals

Atomic Absorption spectrophotometer was used to determine heavy metals concentrations.

2.6.8.1 Procedure for digestion of water samples

The aqua-regia preparation was done by adding 75 ml of hydrochloric acid and 25 ml of nitric acid. This was done in a fume chamber. 25ml of nitric acid was slowly added to 75ml of hydrochloric acid. The aqua-regia is unstable and therefore, it was prepared and used immediately. In a 200-ml conical flask, 50 ml of water sample was added followed by 10 ml of aqua-regia solution. This was then stirred for complete mixing. 1 ml of perchloric acid was added to each of the samples. The flask was then heated to boiling on a hot plate magnetic stirrer until the sample was reduced to about 15 ml and then allowed to cool. Filtration was carried out, and the filtrate transferred to a 50 ml volumetric flask. Distilled water was then added to volume. A blank was also prepared by pouring 50 ml of distilled water and mixing with 10 ml aqua-regia and 1ml of perchloric acid [16].

2.6.8.2 Analysis of samples using Atomic Absorption Spectrophotometer

Calibration standards were prepared for each metal under study. These standards were then aspirated, and the corresponding absorbance recorded [17]. A blank was also aspirated and the difference of the standards absorbances and the blank recorded. The difference gave the actual absorbance of the corresponding standard. The absorbance versus concentration of the standards was therefore used to give a straight-line equation. The sample was then aspirated and from the absorbance, the corresponding concentration was then calculated.

2.6.9 *Escherichia coli*

2.6.9.1 Sample collection, preservation, storage and analysis

The bottle cap was removed and the water collected by inserting the bottle directly into the tap. Ensure that collected sample reached to the 100 ml fill line. The sample bottle cap was then replaced. The sample bottle was placed on ice in a cooler box for the duration of additional sampling and transportation. The date and time of the sampling was recorded. The samples were then taken to the Department of chemistry and put in the incubator. The incubator was turned on. The laboratory bench tops and turn on the Quanti-Tray Sealer (IDEXX 2021) was then sanitized. A green light on the device indicated its readiness status. The sterile gloves were then put on.

The samples were removed from the cooler box and placed on the bench and allowed to warm. The samples were Loged into the laboratory bench sheets. 1 mL of the sample requiring dilution, was pipeted into a sterile sample bottle prefilled with sodium thiosulfate preservative and labeled with the sample number. 99 mL of sterile deionized water was added. The sample container was shaken for about 30 seconds without adding the Colilert reagent to the sample. Colilert reagent snap pack was placed on top of each sample container. The contents of the Colilert snap pack were added to the sample container, the lid replaced, and the sample was mixed by shaking for about 30 to 60 seconds. The sample or diluted sample containing the Colilert was poured into the properly labeled Quanti-Tray. The Quanti-Tray was firmly sat into the rubber template, making sure that the tab was tucked between the tray and the rubber template, to avoid crushing the tray. Slide the tray through the sealer. Properly dispose of the used Colilert snap packs and sample bottles in a biohazard container. The sample trays were then incubated at 35ºC ± 0.5ºC for 24 hours [18].

2.6.9.2 Sample Reading and Quantification

The trays were removed from the incubator. For each tray, the counting was done for the number of large wells and small wells that were yellow for total coliforms. The total coliforms count on the lab bench sheet was recorded. Using an ultraviolet (UV) light and UV viewing cabinet or UV safety glasses, the counting of the number of large wells and small wells that fluoresced for E. coli. The E. coli count was recorded on the laboratory bench sheets. The used Quanti-Trays was then properly disposed in a biohazard container.

3. RESULTS AND DISCUSSION

3.1 Physical – chemical values of borehole water samples

The results of the values of the physical-chemical parameters of water samples in boreholes is presented in the Table 2.

Table 2: The values of physical-chemical parameters of borehole water from Dandora, Kayole, and Pangani sampling sites

Sampling site	physical - chemical values of parameters in boreholes			
	pH	EC (µS/cm)	TDS (mg/L)	TSS (mg/L)
DB	8.20±0.00	241.00±10.00	31.50±0.71	9.50±0.71
KB1	8.06±0.06	230.00±0.50	101.00±1.41	11.00±0.00
KB2	7.50±0.04	473.30±5.60	73.00±0.70	7.00±0.15
PB1	7.70±0.016	246.60±5.80	93.00±1.23	6.00±0.14
PB2	7.80±0.20	236.60±4.61	175.50±1.30	10.5±0.74
PB3	7.80±0.31	256.6±3.60	41.50±0.62	2.00±0.03
NEMA	6.5-8.5	no set guideline	1200	30
WHO	6.5-8.5	2500	1000	NIL
KEBS	6.5-8.5	no set guideline	1500	NIL

Key: DB= Dandora Borehole; KB1, KB2= Kayole Boreholes1,2; PB1, PB2, PB3= Pangani Boreholes 1,2,3; ±SD = standard deviation

According to Table 2, the pH values of the physical- chemical parameters in borehole water samples ranged from 7.5 to 8.2. Kayole borehole 2 (KB2) had the lowest pH value, whereas Dandora boreholes had the highest value. The recommended pH guideline values of WHO, KEBS and NEMA in drinking water was in the range of 6.5–8.5. The pH of all boreholes was within the guideline established by several organizations [19,20,21]; the pH value was within the NEMA/WHO/KEBS guideline limit in drinking water. The electrical conductivity values in borehole water ranged from 230 to 473.3 µS/cm.The largest and lowest values of electrical conductivity were reported at site KB1and KB2 respectively. According to WHO regulations, the permissible limits for electrical conductivity in drinking water should not be more than 2,500 µS/cm. There is no KEBS guideline value. Electrical conductivity of all boreholes values were within WHO acceptable limit [20,22].

TDS levels were between 31.5 and 175.5 ppm. TDS concentrations in borehole water samples were highest in PB2 and lowest in DB. The WHO recommends that the acceptable level for human consumption be not more than 1000 ppm. The NEMA and KEBS maximum guideline values in Kenya are 1200 mg/L and 1500 mg/L respectively. All borehole results complied with WHO, KEBS, and NEMA guidelines [23]. TSS levels varied from 2-11.0 ppm. The concentrations at all the sampling sites exceeded WHO and KEBS guidline values . All the values for all sites for TSS were within the NEMA guideline value of 30 mg/l.

3.2 Anion and ammonia values of physical-chemical parameters in borehole water samples
Table 3shows the values of anions and ammonia parameters in borehole water samples.

Tables 3: Concentrations of anion and ammonia in borehole water samples

Sampling site	Concentration of anions and ammonia in boreholes (mg/L)			
	Chloride	Fluoride	Nitrate	Ammonia
DB	5.70±0.04	0.50±0.10	0.38±0.10	<0.01
KB1	17.07±0.07	3.00±0.14	0.38±0.12	<0.01
KB2	28.44±0.12	1.00±0.01	0.38±0.03	<0.01
PB1	22.76±0.16	2.00±0.06	25.09±0.01	<0.01
PB2	11.37±0.04	4.00±0.17	0.38±0.06	<0.01
PB3	5.70±0.25	0.53±0.10	2.10±0.04	<0.01
NEMA	No set limit	1.5	10	0.5
KEBS	250	1.5	10	0.5
WHO	250	1.5	50	1.5

Key: DB= Dandora Borehole; KB1, KB2= Kayole Boreholes 1,2; PB1, PB2, PB3= Pangani Borehole 1,2,3; ±SD = standard deviation

Chloride levels in boreholes ranged from 5.70–28.4 mg/L. Sampling site KB2 was the highest (28.2 mg/L), while DB and PB3 were the lowest. All the chloride values in boreholes at all the sites were within the guideline values of WHO and KEBS. NEMA had no guideline value. Excessive chloride concentrations corrode metals in the water's supply system. Natural sources of chloride includes sewage discharge, industrial effluents and urban runoff [24].

Fluoride levels in boreholes ranged from 0.50–4.00 mg/L. Sampling site PB3 had the highest value (4.00 mg/L), while KB1 (0.50 mg/L) was the lowest. All the borehole fluoride values conformed to the guideline values except KB2 (3.00 mg/L), PB2 (2 mg/L) and PB3 (4.00 mg/L). From the results, it was evident that a lot of sampling sites had concentrations of fluoride higher than the allowed values by KEBS, NEMA and WHO [25, 26].

Nitrate levels in boreholes ranged from 0.38 to 25.09 mg/L. Sampling site PB1 (25.1 mg/L) was the highest, while DB, KB1 and KB2 were the lowest. All the borehole nitrate values conformed to the KEBS and NEMA guideline values except at site PB1 (25.1 mg/L) which was above. On the other hand, all the values of nitrate in all the sites conformed to WHO guideline value. High nitrate level could have been as a result of run off, wastewater, landfills, animal feedlots and septic tank speelage. Nitrate stimulates excessive algae and phytoplankton formation in aquatic environments, resulting in eutrophication [27].

The ammonia levels in boreholes of the sampling sites were within NEMA, KEBS and WHO guidelines. The ammonia was not detected (detection limit was < 0.01 mg/L) . The most common pollutant in drinking water is ammonia. Human activities in cities, metabolic processes, agricultural and industrial processes, as well as chloramine disinfection, all contribute to the presence of ammonia. Ammonia presence in water increases the chlorine requirement during disinfection processes[28].

3.3 Results and discussion of some selected heavy metal ions

Table 4 shows the concentration of heavy metals in boreholes.

Table 4 Heavy metals concentration (mg/l) in boreholes

Sampling site	Heavy Metals Concentration in Boreholes (mg/L)			
	Zn	Cu	Pb	Cd
DB	0.73± 0.01	1.07 ± 0.02	0.56 ± 0.03	1.50 ± 0.02
KB1	0.65 ±0.10	1.07 ± 0.04	1.16± 0.02	1.50 ± 0.01
KB2	0.65 ± 0.12	1.12± 0.06	1.56 ± 0.01	1.48 ± 0.03
PB1	5.21± 0.01	1.07 ± 0.03	2.25 ± 0.10	1.45 ± 0.11
PB2	8.13 ± 0.05	1.07 ± 0.03	2.41 ± 0.12	1.50 ± 0.12
PB3	8.74 ± 0.04	1.09± 0.04	2.75 ± 0.00	1.61± 0.02
NEMA	1.5	0.05	0.05	0.01
KEBS	5	0.1	0.05	0.005
WHO	5	2	0.01	0.003

Key: DB= Dandora Borehole; KB1, KB2= Kayole Boreholes 1,2; PB1, PB2, PB3= Pangani Boreholes 1,2,3; ±SD = standard deviation.

Zinc levels in the borehole samples conformed to the guideline values except at sites PB1, PB2, and PB3. Copper, lead, and cadmium all had values higher than the NEMA and KEBS guideline values. Cu level in borehole conformed to WHO guideline while Pb and Cd did not.

The high levels of lead could have come from ores in the ground and also from plumbing pipes. Zinc and cadmium levels were also high. Zinc could have been introduced to the water from galvanized roofing materials and water pipes. Zinc can also be introduced by inorganic fertilizers.

3.4 Biological parameters

3.4.1 Biological parameters included Escherichia coli and Total count.

Tables 5 shows the results of all biological parameters in borehole sampling sites.

Table 5: Results of E. coli and total coliform count in boreholes

Sampling sites in Boreholes	E. coli	Total count/100ml
DB	Nil	914
KB1	Nil	248
KB 2	Nil	659
PB1	Nil	64
PB 2	2	16
PB 3	Nil	11

From the data on the bacteriological examination of E. coli and total count, it's evident that most samples showed zero presence of E. coli except PB2. The Total Counts were greater than zero at all the sites.

4. CONCLUSIONS

The pH, EC, TDS, and TSS values of boreholes conformed to the WHO and NEMA guideline values. In the study of chloride, fluoride, nitrate, and ammonia in borehole samples, chloride was found to be within the guideline values. Fluoride was found to conform to the guideline values except at sites KB2, PB2 and PB3. Nitrate in borehole samples conformed to WHO and NEMA guideline values except for PB1, which was above the limit. Ammonia for borehole samples conformed to WHO and NEMA standards. In heavy metal results, zinc levels in the borehole samples conformed to the guideline values except at sites PB1, PB2 and PB3. Copper, lead, and cadmium all had values higher than the guideline values. In the biological analysis of borehole samples, no E. coli was detected except at PB2. DB had the highest count at 914 and followed by KB2 (659). ACKNOWLEDGMENT

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COMPETING INTERESTS

We the authors declare that no competing interests exist.

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