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Assessment of Drinking Water Quality in Mogadishu, Somalia

Abdikafi Elmi Abdishakur, Abdullahi Mohamed Sheikh Ali* and Ahmed Mohamed Hassan

Department of Civil Engineering, College of Engineering and Technology, Abrar University, Somalia

ABSTRACT

The drinking water quality assessment in Mogadishu, the capital and most populous city of Somalia was evaluated in this study. The data were obtained in the year 2019 and subjected to laboratory tests in the Mumtaz Engineering service. Hydro chemical analyses were conducted on twelve samples from six different regions located in Mogadishu with graphical representation of the minimum, maximum and average values of all parameters measured. Coupled with this is the calculation of the Water Quality Index (WQI) for the six regions. One of the main findings of the study revealed that the groundwater from all the regions except for region one is not fit to drink. When a comparison was made across all regions, four regions had a very high TDS above the WHO limit, while two regions had a high EC above the WHO limit. This study recommended that there is a need for proper handling and management of groundwater in the regions with a high concentration of evaluated parameters to avoid bioaccumulation in human tissues through in-take of polluted waters.

***Corresponding author**

Abdullahi Mohamed Sheikh Ali, Department of Civil Engineering, College of Engineering and Technology, Abrar University, Mogadishu, Somalia. Tell: 252615762605; E-mail: marwaanka9@gmail.com

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Introduction

Somalia's position in the world is 44th in terms of mass land and has a good population of about ten million citizens. Mogadishu has been ascribed the position of the biggest city. No city in Somalia has up to a million inhabitants but Mogadishu has more than a million it has a record of about 2.5 million people living there. The remaining population of the people living in Somalia spreads around cities and towns. Based on the United Nations report, about six cities are reported to have between 100,000 to 500,000 inhabitants, coupled with this, there are about 25 cities with less than 10,000 inhabitants (UN, 2019). Going by this UN report, it is believed that Somalia's population is more than this. The reason is that Somalia's are known to migrate mostly to the rural areas. This can be seen in the population report of 1960 where there was a decline in the reported 83%, showing that cities have become bigger by massive migration of people from the rural environment to the urbanized environments of the country. It is reported that Somalia has an annual growth rate of 3% [1].

The adverse effect of this growth rate has increased Somalia's rapid population growth and has weakened the healthcare system of the country making it to become more unreliable. Besides, the population of age group below 30 years in Somalia is now 70%, and this implies that the tendency of having civil unrest is high as claimed by researchers [2]. The climatic condition of the country is semiarid coupled with a warm climate and daily average temperature of 25 - 35 degrees Celsius [3]. The country has two seasons in every climatic year. The first season is the rainy season which is known to take place from the fourth month to the sixth month of the year and from the tenth month to the last month of the year. The second season is the dry season which starts from the last month to the third month of the year, then from the sixth month to the ninth month of the year. Between the sixth to the ninth month of the year, rainfall is experienced in the coastal zone [4]. On average annually, the mean rainfall is 20 to 24 inches is experienced in the South-west and North-west. All year-round, the temperature in the coastal region is always unpleasant and as a matter of fact, Somalia is ranked globally as the country with the highest average temperature (United Nations, 2006).

Groundwater is tapped into via boreholes and shallow wells. Some boreholes' in-depth range from 90m and 250m. Most shallow wells are usually below 20m in depth. This is found common in Mogadishu. In the northern part of the country, the arid and semi-arid climate indicates that all the rivers are transitory and attractive, while their flow is for a short time during and after a heavy downpour. This poses a great challenge to access portable water. In Somalia, about 8.8% of the rural population has significant access to clean drinking water. The huge proportion of the urban population with access to clean drinking water is close to 70% [5].

It is believed that a lot of human activities heavily rest on the quality of water resources. Quality water is a priceless resource to sustain human, animal, and plant life, coupled with health and the environment. In all the industries of any nation, quality water is indispensable and needed to keep up the productivity and the economy of a nation. Even though the value of water to man is beyond common understanding, it is evident that accessibility to quality water by a larger population of humans is hugely limited.

Groundwater is preferred to other sources of water supply because it is readily available through all the seasons, readily accessible, and not easily deteriorated by contamination factors [6]. Groundwater makes up the predominant source of water supply for drinking, domestic, and agricultural purpose in the major parts of Mogadishu, and Somalia in general. It is also an important and essential resource in many rural and urban communities in the central part of Somalia and it functions as a water supply for domestic, agricultural, and industrial purposes [7]. It is an indispensable resource in the central region of Somalia due to the unavailability of other sources. In this area, the demand for water keeps rising daily, and this demand will keep increasing due to the rapidly growing population, increasing urbanization, and poor groundwater productivity of wells due to climate change [8]. In Somalia, there is a wider acceptance of the chemical and biological properties of groundwater. According to Human activities have altered the quality of ground water in regions of Somalia, especially the shallow ground water. Besides, the tendency of groundwater to become polluted by bacteria is very low as compared to surface water. The reason is that the soil and rocks that form a surface for the flow of ground water filter a lot of the bacteria. Bacteria, nevertheless, at times penetrate ground water, seldom in hazardously high concentrations. Having water free from bacterial pollution alone signifies not that the water is safe to consume. At times in the ground water, there can be a huge presence of microscopic dissolved minerals and organic elements in diverse concentrations. Some are not harmful and of advantage, while some are harmful, some may be extremely deadly.

Methodology

The investigations were carried out in different stages. The stages involved were literature review and reconnaissance studies using the existing geologic and physiographic information, laboratory analyses, and discussions. Required materials for the fieldwork were purchased and reconnaissance studies were followed by detailed surface and subsurface geologic and hydrogeological studies and the collection of samples from wells located in Mogadishu. The dataset was obtained from June 2019 up to February 2020. The dataset considers measurements of some physical and chemical indices of ground water obtained by laboratory analytical techniques done by Mumtaz Engineering General Services Company. It is one of the standard laboratories in the whole of Somalia. Stat graphics XVI and, MS Excel was used and compared to WHO (International standards) to check if they fall within acceptable limits. Parameters analyzed were physicochemical and bacteriological factors and comparisons were made with the WHO standards. Notes were taken on the nature of the water in the field before it was taken to the laboratory for further investigations, this is because they are often indicators of degraded water quality. It is best observed in-situ, the reason being that when once water is exposed so many reactions take place which would alter the following; chemistry of the water, color, and odor. The elements were chosen because they are environmentally sensitive and their depletion in the environment, especially in the groundwater systems (which provide our portable and irrigation waters) affects the development and health of plants, animals, and humans.

The city (Mogadishu) was divided into six main regions as shown below in Figure 2.0 and Table 2.0 shows the region's households with their area extent.

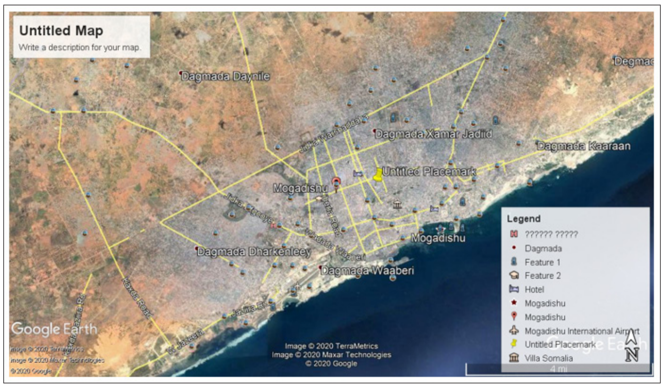

Figure 2.0: Regions of the study

Table 2.0: Regions, households, and their area extent

Regions	Household	Area (m^2)
R1 = Hodan	14000	12600
R2 = Waaberi	18000	402491
R3 = Yaaqshiid	9000	467578
R4= Warta nabada	13000	489851
R5 = Cabdicasiiz	10000	265210
R6= Kaaraan	6000	518117

Data Collection

Samples were collected from 6 regions and each region has 12 samples. The samples collected are from 12 various locations taken at different times and tested in the laboratory. Every three days, a test of one sample was done. In 90 days, all the samples were tested in the laboratory. Another six sets of samples for each region were taken from December up to February.

Water sampling was carried out in the different boreholes in Mogadishu in June 2019, and also December 2020. Hot water was used to sterilize the plastic containers before the collection of the samples. At each sampling borehole, 1L plastic containers with borehole water from the tap which was then allowed to run for two minutes before collection of the samples. Plastic containers were carefully filled with water and recapped. The water samples were acidified with concentrated nitric acid to pH < 2 for total metal analysis.

Seventy-two samples were gathered and analyzed for the concentration of pH, electrical conductivity, chlorine, total dissolved solids, and Turbidity, within the study area. Nitrate concentrations were observed by Hach DR/2000 spectrophotometer with turbid metric formula in tandem with the American Public Health Association.

The membrane filter technique was used to test for coliforms present in the water samples. A determined quantity of water is subjected to filtration, under vacuum through a cellulose acetate membrane of uniform pore diameter, usually 0.54µm. All the bacteria present were retained on the surface of the membrane which is kept on a desirable selective medium in a sterile container and subjected to incubation at an appropriate temperature. Upon the presence of coliform in the water sample, characteristic colonies are observed and they are counted directly.

Laboratory Tests

Thirty-sex wells were identified around the Mogadishu area. Hence, a total of 72 groundwater samples were, at random, collected by the use of pre-washed and sterilized 1 L plastic containers. The collection of all the samples was done when the dry season was at its peak. The time when pollution was expected to be high in this season was chosen. Before the sampling at every location, source water was utilized to wash the containers used for sampling. The samples were kept in the ice chest and moved to the laboratory where they will be analyzed for different physicochemical indices. The physicochemical analyses were carried out within 48 hours of samples collection. Before this analysis, a cellulose acetate filter (0.45-micron Milli-pore filter) was used to conduct the filtration process for the groundwater samples. The pH values were calculated in the collection field by making use of a Hach portable pH meter. Cl- was measured by making use of a Gallenkamp Flame instrument (flame analyzer model FGA 330c). The determination of the concentrations was done using Hach DR/2000 spectrophotometer with turbid metric formula in line with the American Public Health Association Guidelines [9].

The tests were conducted in the Mumtaz Engineering service. The following experiments were done:

i. Turbidity (Turbidity tube model 2100A)
ii. pH (pH comparator)
iii. Total dissolved solids
iv. Electric conductivity
v. Chloride
vi. Nitrate

Water Quality Index (WQI) Calculation for Drinking

WQI is a useful and specific parameter for the identification of water quality and how suitable it is for drinking purposes. It is a representation of the composite determinant for five identified water quality parameters in this study and it provides water quality information to policymakers, lawmakers, and the general public. The calculation is done using the method of weighted arithmetic mean [10]. The method was widely used by scientists. The calculation of WQI is determined using these equations: Table 2.1 presents the WQI value, rating, and grading.

$$\boldsymbol{WQI} = \sum QiWi / \sum wi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: Qi = quality rating, WI=unit weight

$$\mathbf{WI} = k/si \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where k = constant of proportionality= $1(\backslash 1 \backslash \sum wi)$

$$\mathbf{Qi} = (vi/si) \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where: VI=observed value

Si= standard value

Table 2.1: Water quality index

WQI Value	Rating of Water Quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very Poor water quality	D
Above 100	Purposes	E

Result and Discussion

Hydrogen Ion Concentration

pH of all the regions was compared, and the average, minimum, and maximum pH levels of each region were taken and represented graphically in Figure 3.0. It was seen that the maximum concentration of pH among all was region 5 which is a slightly alkaline type of water, the minimum concentration among all was a region, 2 which is a slightly acidic type of water due to CO_2 gas from the atmosphere and is not within (WHO, 2011). Acceptable limit. A level that is typical to all the regions was also taken into consideration.

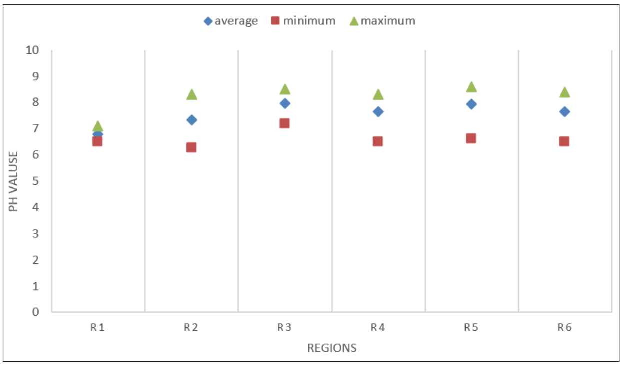

Figure 3.0: Comparison of pH concentrations of different regions

Electrical Conductivity

Electrical conductivities, EC the numbers that are typical of all the regions were noted and represented in figure 3.1. The highest value among all was seen in region 5whereas the least is region 1 and were all represented graphically as shown below.

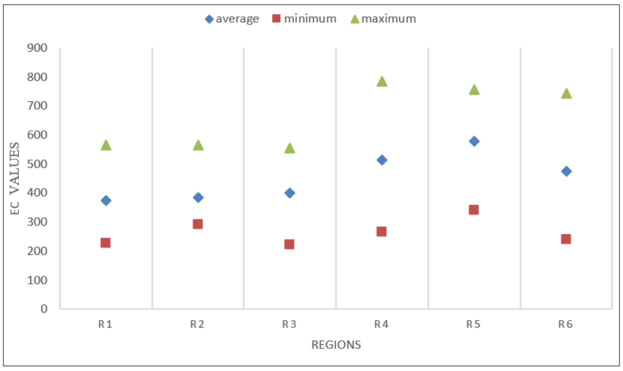

Figure 3.1: Comparison of EC concentrations in different regions

Chlorine

Chloride ion concentration, Cl- in Figure 3.2 has a common and unique representation in all the regions that were observed. A level that is typical to all the regions and the maximum value was noted in R5 where the minimum value or the lowest is R2.

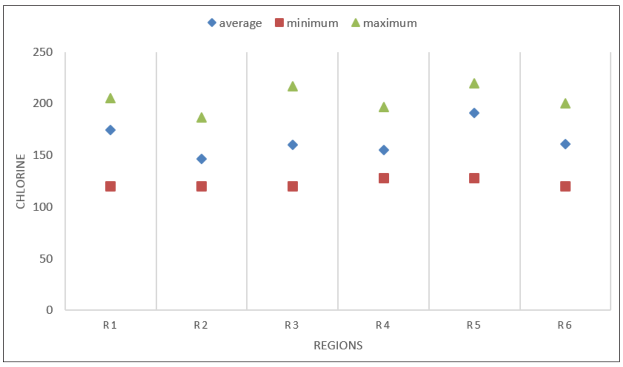

Figure 3.2: Comparison of Cl concentrations in different regions

Total Dissolved Solids

In figure 3.3 TDS, the highest concentration was seen in region 3 among all the 6 regions, it is important to note that this may influence the pleasant water quality, disturbing laundry activities, and corrosion of household pipes. It was also observed that all the regions have a high concentration of TDS which may be caused by salt deposits, mineral springs, toxic ions, seawater effects, etc

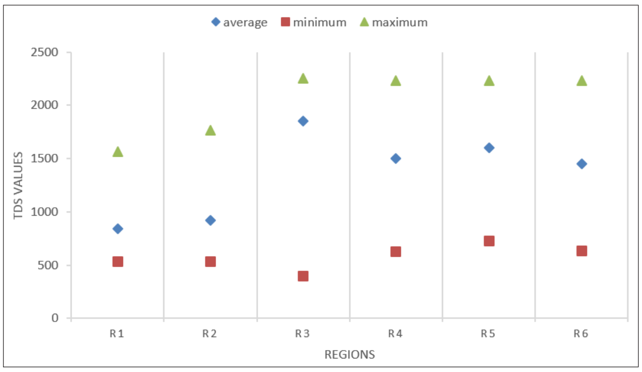

Figure 3.3: Comparison of TDS concentrations in different regions

Turbidity

Turbidity of all regions was compared, the average, maximum, and minimum, and also shown in Figure 3.4, the maximum value noted was in regions 2. Excess turbidity may concern health because turbidity gives shelter to some pathogens. The cloudiness of the water may be influenced by changes in water movement, point source contamination, and wastewater.

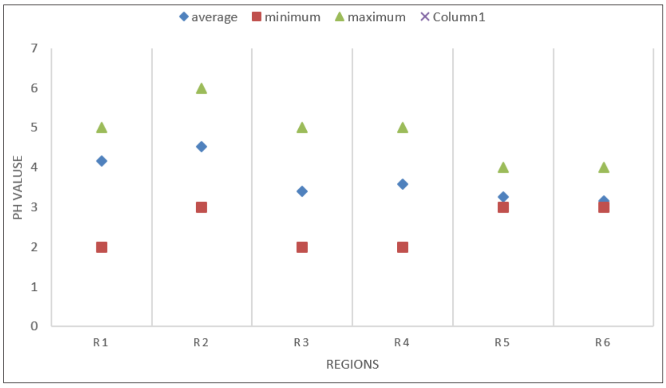

Figure 3.4: Comparison of TUB concentrations in different regions

Comparison of Regions Based on Parameters

The average concentration of pH was insignificantly different in all the six regions of this study except for region one. Comparison among regions showed that region three and region one had the highest maximum and minimum values of pH respectively than others. In other words, it can be deduced that all the water bodies of the six regions are not acidic. However, the maximum value of region three is of concern as it is getting close to the extreme of the WHO limit. Having this high value maybe because of the soil composition or where the water comes from. The high maximum value tends towards a more alkaline nature which can also signify the presence of limestone in the surroundings of region three water.

The EC in the water body for all the region from minimum to maximum vary both below and above the WHO recommended limit for all the regions. The mean EC differs across all the regions significantly, especially in regions four, five, and six. The maximum and minimum values of EC are found in region five and region one respectively. Care must be taken about the region's five water bodies as it may increase if pollutants gain entry into the water, rendering the water unsuitable for consumption and posing a health risk for the consumer.

In all the six regions of this study, the chlorine maximum and minimum values are suitably good for water meant for consumption. As it has been discovered in the findings of this study, region five has the highest mean chlorine value while region two has the lowest mean value. Other regions are within the expected range with varying average values. A region that tends to increase more in chlorine content will be region five and this will be alarming as the water body will position itself as a menace to the health of the consumers. Meanwhile, the chlorine concentration must not be too low as it may increase the presence of pathogens and other pollutants that are harmful to human and aquatic life. Care must be taken on all regions so that chlorine concentration will be in check either during the rainy season or dry season.

The average TDS values are higher in all the six regions than the WHO limit except for regions one and two. All the maximum values of the turbidity are higher than the WHO limit. This is very alarming. Generally, TDS cannot be dissociated from the suspension of particles in the water. All the water bodies in Mogadishu are not free of suspension, just it is in varying quantities. The regions with the most presence of suspension of substances are regions four and region five. Although organic materials can be present naturally in the region water body, they can be essential to human and plant life. However, in the regions, TDS presence in high concentrations can lead to increased turbidity in the water, and when they are not filtered, diseases are unavoidable.

Turbidity in all regions is on the brink of becoming higher than the WHO limit. However, they have a different mean which is below the WHO limit. This is expected as seen in the TDS concentration in all the regions. These dissolved solids become sediments present on the floor of the water body which is why turbidity is at appalling levels in terms of concentration in most regions. Caution must be taken in all the regions right from the TDS so that turbidity can be reduced to a healthy level.

It is generally considered the least polluted compared to other inland water resources, but studies indicate that ground water is not free from pollution though it is likely to be free from suspended solids. The major problem with the ground water is that once contaminated, it is difficult to114 restore its quality. Hence there is a need and concern for the protection and management of ground water quality. It is well known that no straightforward reasons can be advanced for the deterioration of water quality, as it is dependent on several water quality parameters.

Health Effect

In some of the regions in Mogadishu, the physical characteristics of the water will be good for consumption except for the samples with high TDS which will show suspended particles in consumed water. Discovering water with high TDS concentration is in tandem with the findings of whose study about water quality in Mogadishu showed that the drinking water in the city has small floating particles present in them. So far, there have been no single studies that have identified the relationship between high TDS concentration and diseases among humans and this signifies that no negative effect will be traced to the health of the inhabitants in the areas with samples with high TDS.

Since turbidity is sometimes associated with microbial pollution. It can hinder the activities of disinfectants in water treatment thereby creating a medium for the growth of microorganisms Considering the acceptable recommendation of WHO of 5 NTU, it can be ascertained that the water quality of Mogadishu is healthy for daily consumption. However, the health effect is not common or sparingly uncommon when there is a high level of turbidity in water.

Likewise, in all the regions, the chlorine concentration is not above the WHO recommended limit. Its presence in water is the appropriate concentration and can effectively disinfect various microorganisms and some pathogens such as protozoan parasites, Giardia, and Cryptosporidium [6]. Even though it is good in the water and one of the cheapest means of disinfecting the water bodies, it comes with a price. Continuous exposure can cause cancer. Such as bladder and rectal cancers Based on research, the byproducts of chlorine can stimulate the excess production of free radicals in the human body and these radicals are potent to damage the human cells and extremely carcinogenic. Other health risk associated with continuous exposure to chlorine includes giving birth to children with brain defects or heart problem. This calls for Mogadishu water regulatory body to protect human life from the harms of consuming chlorine.

High pH is not common in the regions of Mogadishu and this signifies not water alkaline in nature in the regions. This implies that there will be no delayed growth and impairment to the organs of the body, for instance, the olfactory organs, and eyes.

Electrical conductivity itself is a reflection of many pollutants are present in the water. So having high EC will be harmful to human and aquatic life. Waterborne diseases will be epidemic in regions with high EC, such as cholera, typhoid fever, diarrhea, and so on. Since the EC in Mogadishu is below the recommended limit, the health life of the inhabitants is not at risk.

Water Quality Index

Water Quality Index allows researchers to have a gross analysis of water quality on numerous levels with the effect on water's quality to foster aquatic life and if the general quality of water body will be a possible threat to several waters uses. The calculation of WQI for region one was done, and this calculation was applied for all the remaining five regions. Table 2.2 is generated which shows WQI for regions one to six.

In the six regions, the average WQI value for region one is 44.96 which reveals that water quality is good, the average WQI for region two is 60.84 which depicts that the water quality is poor, the average WQI for Chlorine region three is 63.14 which shows that water quality is poor, the average WQI for region four is 57.70 which shows that the water quality is poor for drinking purpose, the average WQI for region five is 60.43 which depicts that the water quality is poor, and finally for region six, the average WQI is 52.70 which depicts that the water quality is poor. WQI values in all regions, except for region one, show that water quality decline, and more care must be put in place to improve the water quality. It is obvious from the index that all of the parameters require serious precautions to be utilized for human consumption. Except for region one, the cumulative drinking WQIs of the regions are well positioned in the poor range. This necessitates more protection of the five regions (especially in regions with high TDS) since suspended materials in the water are attributed mostly to discharge from sewage in the areas where humans dwell. Since one of the main aims of Mogadishu water resources management is to execute plans driven toward the conservation of water quality, it would be compulsory to have a sustainable monitoring program in designated regions. These plans coupled with the creation of domestic wastewater treatment stations for known discharging points in the regions could be one of the possible solutions to positively change the indices, which demonstrate the betterment of the regions' water quality.

Table 2.2: Water Quality Index Matrix for all Regions

Regions	Parameter	Observed value (vi)	Standard value (Si)	Unit weights (Wi)	Quality rating (qi)	Wi x Qi	WQI value	Water Quality Rating
R1	pH	6.79	8.5	0.34	-14	-4,76	44.96	Grade B Good water quality
	Electrical conductivity (µS/cm)	373	500	0.005	74.6	0.37		
	Chlorine (mg/l)	174.3	250	0.011	69.72	0.76		
	Total dissolved solids (mg/l)	843.17	1000	0.002	84.32	0.16		
	Turbidity	4.17	5	0.58	83.4	48.37		
	Nitrate	0	50	0.058	0	0		
R2	pH	7.33	8.5	0.34	22	7.48	60.84	Grade C Poor water quality
	Electrical conductivity (µS/cm)	385.60	500	0.005	77	0.38		
	Chlorine (mg/l)	146.5	250	0.011	58.6	0.64		
	Total dissolved solids (mg/l)	921.91	1000	0.002	92.19	0.018		
	Turbidity	4.53	5	0.58	90.6	52.34		
	Nitrate	0	50	0.058	0	0		

R3	pH	7.98	8.5	0.34	65.33	22.21	63.14	Grade C Poor water quality
	Electrical conductivity(MS/M)	399,71	500	0.005	79.94	0.39		
	Chlorine (mg/l)	160	250	0.011	64	0.70		
	Total dissolved solids (mg/l)	1850	1000	0.002	185	0.37		
	Turbidity	3.41	5	0.58	68.2	39.55		
	Nitrate	0	50	0.058	0	0		
R4	pH	7.65	8.5	0.34	43.3	14.73	57.70	Grade C Poor water quality
	Electrical conductivity (MS/M)	513.97	500	0.005	102	0.51		
	Chlorine (mg/l)	155	250	0.011	62	0.68		
	Total dissolved solids (mg/l)	1503.4	1000	0.002	150	0.30		
	Turbidity	3.58	5	0.58	71,6	41.52		
	Nitrate	0	50	0.058	0	0		
R5	pH	7.93	8.5	0.34	62	21	60.43	Grade C Poor water quality
	Electrical conductivity(MS/M)	579	500	0.005	115.8	0.57		
	Chlorine (mg/l)	191	250	0.011	76.4	0.84		
	Total dissolved solids (mg/l)	1600.83	1000	0.002	160	0.32		
	Turbidity	3.25	5	0.58	65	37.7		
	Nitrate	0	50	0.058	0	0		
R6	pH	7.65	8.5	0.34	43.3	14.7	52.70	Grade C Poor water quality
	Electrical conductivity(MS/M)	473.86	500	0.005	94.7	0.47		
	Chlorine (mg/l)	161.25	250	0.011	64.5	0.70		
	Total dissolved solids (mg/l)	1448	1000	0.002	144.8	0.28		
	Turbidity	3.16	5	0.58	63.2	36.6		
	Nitrate	0	50	0.058	0	0		

Water Quality

The WQI values calculated in this study revealed that the water quality in all regions except region one is poor for either household use or the aquatic environment. For the household use and aquatic environment, the excellent WQI values are 0-25. Similarly, for good WQI values, it ranges from 26-to 50. None of the regions' WQI fell into the excellent range. Only region one was found to be in the good water quality range. Other regions were found to be in the poor WQI range. Poor prevailing sewage systems and unprocessed wastewater discharged from households, and run-offs from farmlands can be prominent reasons why most regions are found in the range of poor WQI. The implication of the poor water quality as discovered in this study is that water in Mogadishu will not be fit for human consumption but may still be utilized for agricultural purposes. This is why it is essential to subject the Mogadishu water to constant observation and management process provided the water is to be consumed and utilized for agricultural purposes.

Conclusions

Those areas with high TDS and EC have also high Cl, which indicates that the degree of pollution within these locations was not only by intrinsic properties of soil but also, more importantly by human activities. This appalling concentration might also accompany the uncomfortableness of the people living in the vicinity of those regions (R4, R5, and R6).

A high level of TDS and low pH shows that there is the presence of other harmful pollutants in the water. For example, pollution and other toxic elements can result from high-level concentrations of TDS, EC, Cl, and pH so it is important to constantly observe and record these changes which can act as an advance cautionary sign that something is happening to the water.

The quality and suitableness of groundwater in the Mogadishu region for human intake have been assessed. As found in the result of this study, the undermentioned conclusions are made: (1) None of the samples in all the regions are acidic while very few are alkaline; (2) The EC is satisfactory but an increase in EC of the regions will occur if the increase in temperature occurs and vice versa; (3) Most of the regions according to the (WHO, 2011) permissible limit has Chlorine concentration at the limit in water and any slight increase in chlorine can be hazardous to human intake and other living organisms. It was obvious from the results that TDS was high and above the WHO acceptable limit for drinking water.

Recommendations

There is hence a need for effective management of water multi-criteria event present and future health and environmental issues due to prolonged exposure to effects of high TDS, EC, and slightly acidic pH medium in some areas through drinking and domestic uses. The water filtration process, including a high-efficiency water softener to bring down hardness, can offer solutions. An expert can help to evaluate things like mineral content and total dissolved solids.

Government should ensure the provision of potable water for the communities as this would go a long way to preserve the health of the people. Also, an adequate geochemical investigation should be carried out before boreholes are drilled in multi-criteria to reduce the possibility of the groundwater contamination.

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