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RESEARCH ARTICLE

PHYSICO-CHEMICAL ANALYSIS OF GROUNDWATER IN THE GAZI-MRIMA HILL REGION OF KWALE COUNTY, KENYA

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ABSTRACT

195 groundwater samples were collected in the dry period of February/March. These were analyzed for Mn, Cd, Pb, Cu and Zn concentration by atomic absorption spectrophotometer and the results compared with the US EPA action levels. Mn and Cd groundwater pollution was the most prevalent with 42 % of all samples having concentration of each element above the EPA action level. 23 % and 11 % of the samples had respectively Pb and Cu levels above the EPA limits while none of the samples had elevated Zn concentration. Overall, 80 % of the groundwater samples had at least one of the heavy metals analyzed above the EPA action level.

Key words: Groundwater, drinking, heavy metal, elevation, rural setting

INTRODUCTION

Water brings forth life, it rejuvenates, it cleanses, it purifies; water is a basic amenity that the human race needs to survive. As much as it is essential to life, water may also be a source of disease and ill health to the general public if its quality standards are compromised. Due to its chemical nature, water will always contain minerals and organisms that it collects from materials it comes into contact with. Depending on their type and concentration, these constituents may be toxic and therefore harmful to human beings (Elinge *et al.,* 2011). In most parts of the world microbial quality of water is often given the first priority given the immediate and potentially devastating consequences of waterborne infectious diseases (Schmoll *et al.,* 2006). The recent past however has seen increased concern over the content of heavy metals in drinking water as the public becomes more aware of their strong toxicity and the impact they have on human health. Most heavy metals occurring in nature are not harmful at trace concentrations and some such as Fe, Cu, Co, Mn, Zn and Cr are even essential for the proper functioning of the human body (Ismael *et al.,* 2011; Amartey *et al*., 2011).

All metals however are toxic at higher concentrations, with their toxicity being linked to chronic diseases such as renal failure, liver cirrhosis, hair loss and chronic anemia is documented (Salem *et al.,* 2000). Groundwater is an important source of drinking water in most parts of rural Kenya. This is mainly because groundwater is often available close to where it is needed and can thus be developed at a relatively low cost and in stages to keep up with any rising demand. Once the source of water has been identified however, priority is often given to the quantity rather than the quality of water. While groundwater may be considered safer in terms of microbial quality compared to surface water due the filtering effect of the overlying rock and soil, it is not entirely fail-proof. Pollutants such as heavy metals can find their way into the groundwater through seepage of effluents and chemicals arising from human activities, or from leaching and dissolution of metals occurring naturally in rock and soil. Many people the world over look at the quality of drinking water mainly from the aspect of microbial contamination. Other types of water pollution such as heavy metal contamination are often relegated to the background and are only brought to the fore if contamination particularly due to anthropogenic sources such as improper disposal of waste is suspected. In this respect, little attention is given to heavy metal content in drinking water in many rural areas owing to the relatively fewer anthropogenic sources of pollution. This notwithstanding, groundwater in rural areas may still be vulnerable to heavy metal contamination arising from obscure sources such as use of fertilizers and the existence of natural deposits of mineral resources.

The Gazi-Mrima Hill region is a rural area in which the residents rely mainly on small scale farming for subsistence. The region also has a high natural background of mineral resources. According to the Kwale District Environmental Assessment Report (1985), the region is endowed with a variety of mineral ores such as iron, limestone, zinc, zircon, gypsum, manganese, lead, niobium, titanium, molybdenum, monazite (a calcium phosphate compound), nepheline (a potassium sodium and aluminium compound) and gorceite (abarium aluminium phosphate compound). Copper and zinc ores are also known to exist, according to the Government of Kenya (2008) State of the Coast report. This notwithstanding, the local residents use untreated groundwater from shallow wells sunk indiscriminately in the region for drinking and

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other domestic purposes. The main objective of the current study was to determine the quality of groundwater from the shallow wells in the Gazi-Mrima Hill region in terms of heavy metals namely Mn, Cd, Pb, Cu and Zn. Data from this study will provide vital baseline information against which public health risk may be assessed.

MATERIALS AND METHODS

Study area

The study area lies within the area bounded by the longitudes 4^0 21' 11" S and 4^0 38' 41" S and latitude of 39^0 10' 30" E and 39^0 30' 24" E. The geology of the area is characterized mainly by coral limestone of Pleistocene age and Magarini sands. The Magarini sands consist of unconsolidated sediments derived from the Duruma sandstone series that were deposited during the tertiary ages. There are two distinct rainy seasons in the region: the short rains season experienced from October to December and the long rains season that begins in late march and extends to late June. The region has a typically high water table making groundwater accessibility relatively easy. Groundwater abstraction is via shallow hand-dug wells of depth ranging from less than a meter to approximately 75 m. Majority of the wells are open and prone to siltation. In the dry seasons, some of the wells dry up in the heat of the day thus limiting their use to a few hours in the morning.

Sampling

Sample collection was done during the dry period of February/March. A total of 195 ground water samples were collected from fourteen Villages namely Gazi, Kanana, Msambweni, Mwambao, Kikoneni, Mushiu, Shirazi, Ramisi, Mrima Hill, Mwendo wa Bure, Mlalani, Munje, Majoreni and Nikapu. Sample collection was done using 500 ml polyethylene bottles which had been cleaned with detergent and water, rinsed off with 10% nitric acid, then by distilled water and finally with the sample water before collection. Water samples were obtained from the wells in a manner similar to that used by the local residents. Analysis of pH and electrical conductivity of the samples was done on site. The samples were ferried to the laboratory where they were acidified using concentrated nitric acid to a pH of less than two as a preservation measure. They were then left to sit for at least 72 hours before analysis.

Instrumentation and analysis

Analysis of pH and electrical conductivity of the water samples was done using standard digital meters while that of heavy metals was done using GF-990 flame atomic absorption spectrophotometer (AAS) at the School of Pure and Applied Sciences, Pwani University College, Kilifi, Kenya. The AAS working parameters for the different metals are shown in Table 1. Calibration plot method was used. This involved the gradual dilution of a stock solution of the heavy metal of interest to known concentrations in the range in which Lambert-Beer's law holds. The different concentrations were then aspirated into the acetylene – air flame. With a cathode lamp of the element of interest as the source of light, absorbance of light was measured for the different concentrations of the stock solution and a calibration curve of absorbance versus concentration generated. The calibration curve was then used as the standard of reference against which the concentration of the particular heavy metal in sample was determined. This was repeated for all the heavy metals of interest. Each sample was acid digested in preparation for analysis. This involved adding 2 ml concentrated nitric acid and 1 ml concentrated hydrochloric acid to 100 ml of each sample. The resulting solution was then heated at a solution temperature of 95 ^{0}C ± 5 ^{0}C up until the volume fell to 20 ml. The concentrate was left to cool before being topped up to 100 ml using double distilled water. This was then filtered using 0.45µm pore size filters into 100 ml polyethylene bottles in readiness for analysis. The procedure was repeated for all the samples. To correct for the acids used in the digestion process, a blank was prepared in the same manner as the samples using the double distilled water. The blank and the digested samples were then always run together and final concentration of metal of interest given less the concentration of the blank (if any).

Table 1: AAS working parameters

Element of interest	Analyticical line (nm)	Detection limit (mgl^{-1})	Working range (mgl^{-1})
Manganese	279.5	0.002	0.01 - 3.5
Cadmium	228.8	0.0028	0.02 - 2.20
Lead	217	0.0012	0.08 - 14
Zinc	213.9	0.003	0.01 - 3
Cu	324.7	0.004	0.018 - 4

RESULTS

Table 2. presents the mean values of pH, electrical conductivity (EC) and heavy metal concentration of water samples from the various villages in the sampling area. The results show that groundwater in the sampling region is alkaline. The US EPA has classified pH as a secondary water standard, recommending an admissible limit of 6.5-8.5. Out of the 14 villages, 6 had mean levels of pH above the EPA admissible limit. The highest mean pH level was 9.9 reported in Kanana while the lowest was 7.2 in Mrima Hill. Electrical conductivity is a measure of water's ability to conduct electric current and while it does not give an indication of the specific elements present, it is a good indicator of the presence contaminants such as sodium, potassium or sulphates (Adegbola *et al*., 2012). The mean electrical conductivity of the groundwater samples ranged from 352.3 – 1824.4 µScm^{-1} with 5 villages reporting values below 500 µScm^{-1}.

Table 2: Mean values of pH, EC (µScm^{-1}) and heavy metal concentration (mgl^{-1})

Village	pH	EC	Mn	Cd	Pb	Cu	Zn
Gazi	9.5	488.5	0.01	0.01	BDL	0.24	0.01
Kanana	9.9	460.3	0.06	0.09	0.09	0.84	0.04
Msambweni	7.9	1464.7	0.09	BDL	0.24	0.39	0.04
Mwambao	9.3	352.3	0.06	0.05	0.03	0.47	0.04
Kikoneni	8.0	1068.7	0.13	0.05	BDL	0.45	0.05
Mushiu	7.3	485.6	0.32	0.02	0.01	1.04	0.05
Shirazi	9.3	1029.1	0.13	BDL	0.31	0.41	0.07
Ramisi	9.3	575.6	0.16	0.02	0.33	0.28	0.08
Mrima Hill	7.2	862.1	0.41	0.04	BDL	1.05	0.08
Mwendo wa Bure	9.6	463.2	0.13	0.10	0.03	0.11	0.11
Mlalani	8.0	608.1	0.06	0.01	0.14	0.37	0.16
Munje	8.0	1293.6	0.03	BDL	0.24	0.44	0.20
Majoreni	7.4	1842.4	1.64	0.07	0.01	0.74	0.36
Nikapu	7.3	574.8	0.07	0.03	BDL	0.15	BDL

Samples from Shirazi, Kikoneni, Munje, Msambweni and Majoreni had high electrical conductivity with mean values of 1029.1, 1068.7, 1293.6, 1464.7 and 1842.4 µScm^{-1} respectively. Of the heavy metals analyzed, detectable amounts of Mn and Cu were observed in samples from every village, with mean values ranging from 0.01-1.64 mgl^{-1} and 0.11-1.05 mgl^{-1} respectively. While the mean concentration of Cu in the villages was within the EPA limit of 1.3 mgl^{-1}, the mean concentration of Mn was above the EPA action level of 0.05 mgl^{-1} in 12 of the 14 villages. Cd was detected in 11 villages and at a mean concentration exceeding allowable limit of 0.005 mgl^{-1}. Elevation of Pb was evident in 8 villages while Zn was within the EPA limits in all villages. The EPA limits for Pb and Zn are 0.015 mgl^{-1} and 5 mgl^{-1} respectively. Fig. 1 gives the percentage of wells in each village with elevated concentrations of at least one heavy metal while Fig. 2 shows the contribution of each heavy metal to overall pollution of groundwater for the entire sampling area. All metals are toxic at high concentrations and the elevation of any one of them in a sample renders the source unsuitable for human use. In this respect, Gazi had the least polluted groundwater with about 18 % of the samples having the concentration of at least one of the metals above EPA permissible level. Nikapu and Kanana on the other hand had highest incidences of groundwater pollution 100 % of the sources being unsuitable for human use. For the entire sampling region, 80 % of the 195 groundwater samples were polluted by at least one of the heavy metals analyzed. The poor quality of groundwater in the sampling region was mainly due to Mn and Cd with the contribution of each standing at 42 %. This was followed by Pb at 23 % and Cu at 11 %. Occurrence of Zn in all the water samples was within the EPA allowable limits.

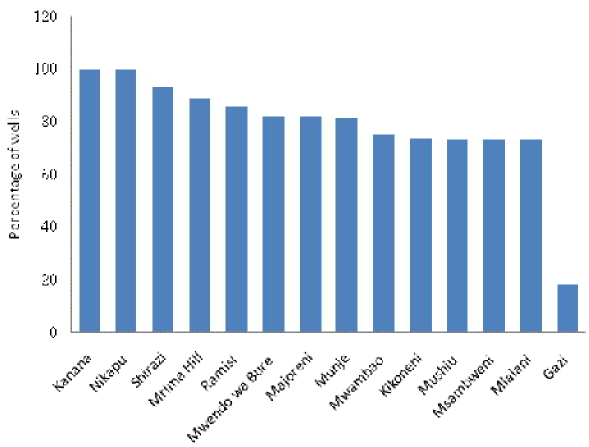

Fig. 1: Percentage of wells per village contaminated by at least one heavy metal

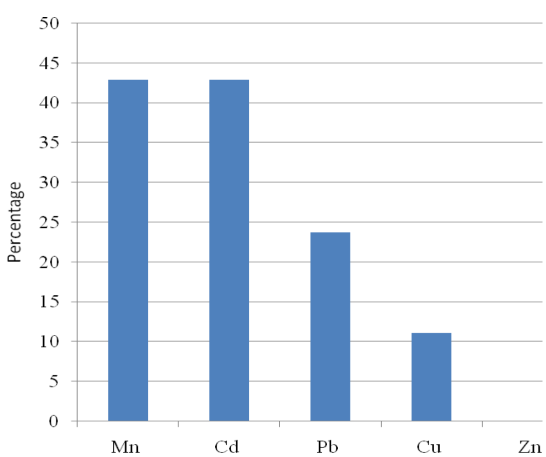

Fig. 2: Percentage contribution of selected heavy metals to ground water pollution in the sampling region

DISCUSSION

Existence of deposits of Mn, Pb and Cu ores in the region is documented; Cd on the other hand is found in ore deposits such as zinc and phosphate ores, both of which are present in the sampling region. Thus, there exists a possibility that the groundwater is naturally enriched with the heavy metals due to the presence of mineral ores in the region. While the region has no major mining or industrial activities, small scale farming is usually undertaken by the local residents. Use of fertilizers such as those derived from phosphates may also introduce heavy metals such as Cd in the groundwater system. The high alkalinity of groundwater is characteristic to the coastal region and may be attributed to the calcium carbonate from broken down coral skeletons and limestone in the local geology. The sampling region is in close proximity to the Indian Ocean. Consequently, sea water intrusion is likely to affect some region within the sampling area. This, coupled with the presence phosphate ores in the region, may enhance EC of groundwater. The region however is also crisscrossed by underground rivers some of which are responsible for fresh water aquifers the Tiwi aquifer (Tole, 1997). This could explain the reduced pollution of groundwater in some areas within the sampling region such as Gazi.

Conclusion and Recommendation

Groundwater in the larger part of Gazi-Mrima Hill region is of poor quality and not suitable for drinking. However, small pockets of groundwater with relatively good quality are evident in the region. Thus, there is need to treat groundwater from the region before it is availed to the public. The pockets of freshwater can also be harnessed for redistribution to the local residents. With such high content of heavy metals in drinking water, research is needed to determine the impacts, if any on the health of the Gazi-mrima Hill residents.

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