Dissolved organic carbon (DOC) and coliform bacteria in underground waters in areas around Nairobi

Baptista M. Kimei, Sumesh C. Chhabra*, and Gathu Nyagah

Kenyatta University, Chemistry Department, School of Pure & Applied Sciences P. O. Box 43844, Nairobi, Kenya.

*To whom correspondence should be addressed. (email: scchhabra@avu.org)

SUMMARY

Most people in areas surrounding Nairobi use untreated underground waters for their domestic chores. A study was carried out during the wet season (April-June) and the dry season (September-November) of the year 1994 to find out if these untreated underground waters contain dissolved organic carbon (DOC) and coliform bracteria. Out of the 40 sites sampled during both the wet and dry seasons, 11 contained colifrorm bacteria during the wet season, while only 2 contained the microbes during the dry season. The microbes were detected only in the wells. DOC was detected in 37 sites during the wet season and in 31 sites during the dry season within a range of 2.0-30.8 mg L^{-1}. DOC which mainly consists of humic and fulvic acids was quantified by measuring their absorbance at 360nm by UV-VIS spectrophotometry. The presence of coliform bacteria was detected by use of microbiological techniques.

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Introduction

About 60% of the persons in developing countries live without an adequate supply of clean drinking water and about 75% without any kind of sanitary facility [1]. Many communities in these countries depend on underground water for their domestic consumption.

Over 50% of the population live in the rural areas. A large proportion of this population live in arid and semi-arid areas and use untreated underground waters. Ground water is usually assumed to be a very good source of drinking water because of the purification properties of soil [2]. However, underground water may be subject to pollution and may not be as safe as is generally assumed [3]. This is because these waters may contain some biologically toxic substances such as dissolved organic carbon and pathogenic microbes. In the present work, a study was carried out to find if untreated water samples from underground sources in areas surrounding Nairobi contained Dissolved Organic Carbon (DOC) and coliform bacteria (microbes).

Treated water samples were obtained from Kenyatta University and Kabete. Water Works were also analysed for dissolved organic carbon (DOC) and coliform bacteria.

Material and Methods

Equipment

UV-Vis Spectrophotometer SP-20 (Roy Milton Co. Ltd., London).

Determination of Dissolved Organic Carbon (DOC)

Sampling. Samples from three Divisions, Kangundo in Machakos District, Kikuyu in Kiambu District and Ngong in Kajiado District were collected each during the wet (April-June) and dry (September-November) seasons of the year 1994. Samples were collected from 15 sites in Kangundo, 13 sites in Ngong and 12 sites from Kikuyu. Sites were chosen on demographic factors and a distance of at least two kilometres. Treated water was also collected from Kenyatta University and Kabete Water Works during both the wet and dry seasons. Five samples were collected from each site during each season. Samples (each 250 mL) in polyethylene bottles were collected and transported overnight and kept in a refrigerator until analysis time. This was to inhibit metabolic processes of microbes and biodegradation reactions that could significantly alter the levels of dissolved organic carbon (DOC). Samples were filtered using 0.45 μm fibre-glass filter prior to analysis.

Analytical Procedure

DOC concentrations in underground water samples collected from the three Divisions Kangundo, Kikuyu and Ngong around Nairobi were determined by recording the absorbance of the samples at 360 nm in a 1 cm cell using a UV-Vis spectrophotometer SP-20 (Roy Milton Co. Ltd., London) and substituting the absorbance in equation (1) for DOC/absorbance relationship. Each sample was run three times and the mean taken as representative of the sample. The mean of the five samples was taken as representative of each site.

$$\text{DOC (g m}^{-3}) = 59.6\ \text{Abs}_{1\ \text{cm}} + 1.9 \quad \dots\dots\dots\dots \quad \textbf{(1)}$$

where, $\text{Abs}_{1\ \text{cm}}$ = Absorbance in a 1cm cell.

The equation (1) has earlier successfully been used to predicted levels of DOC in soft waters [4, 5]. This method is superior than most of the conventional methods [6-8] used for measuring DOC concentrations.

Determination of Presence of Faecal Coliform

Sampling. Three samples (each 250 mL) were taken from each site in polythene bottles, which were thoroughly cleaned with detergent and rinsed with distilled deionised water. The bottles were then sterilized when closed in an autoclave at 120°C and a pressure of 2355 N/m^2.

The bottles were carried to the collection site and submerged in water before opening to avoid contamination by aerial bacteria. The samples were transported overnight and kept in a refrigerator to prevent microbial activities such as multiplication and the die off rate.

Screening Method

The analysis of water for the presence of faecal coliform bacteria was carried out in three steps: the presumptive, the confirmed and the completed tests [9]. The adopted procedure is the one recommended by United States Environmental Protection Agency that ruled out enumeration of faecal coliform bacteria in potable water samples and instituted regulations based only on the presence or absence of faecal coliform bacteria [10].

Results

Levels of DOC and the presence of faecal coliform bacteria found in wells and boreholes in Kangundo, Ngong and Kikuyu Divisions are listed in Tables 1, 2 and 3, respectively.

Discussion

DOC was detected in 37 sites during the wet season and in 31 sites during the dry season. The levels of dissolved organic carbon were high during the wet season during which the lowest and highest values detected were 2.0 g m^{-3} and 30.8 g m^{-3}, respectively.

DOC was more prevalent in open wells found mostly in Kangundo Division. There are mainly two factors that determine the amounts of DOC in underground waters: The way the well is constructed and the water catchments area of a particular aquifer. Open wells contained more DOC brought in by surface water run-off than covered wells. Aquifers whose water catchments areas are forested areas contained more DOC than aquifers whose catchments areas are cultivated farmlands. DOC was high during the wet season because rain dissolves previously bond DOC on soil particles and accelerates decay of plant and animal remains which are the sources of DOC. DOC decreases drastically during the dry season due to biodegradation where DOC is broken into smaller molecules such as methane, carbon dioxide and hydrogen sulphide. DOC biodegradation is also accelerated by high temperatures, which provide optimum temperature for bioactivity of decay causing soil bacteria.

Table 1. Level of DOC and presence of faecal coliforms in wells and boreholes in Kangundo Division, Machakos District.

Site/Substance	DOC ($g\ m^{-3}$)		Coliforms		Depth of well (m)
	Wet	Dry	Wet	Dry	
Kithimani	20.40±0.20	2.20±0.80	Present	nd	6
Nguluni	9.30±0.75	2.70±0.40	nd	nd	107
Kwa Musembi	10.80±0.40	3.10±0.30	Present	Present	8
Isooni	4.90±0.20	nd	Present	Present	5
Sengani	5.50±0.15	2.40±0.10	nd	nd	8
Tala	3.10±0.20	2.10±0.10	nd	nd	122
Vangala	2.50±0.20	nd	nd	nd	8
Kalandini	11.70±0.50	2.80±0.50	Present	nd	14
Katine	nd	nd	nd	nd	6
Kyaume	16.80±0.70	4.90±0.50	nd	nd	9
Kitunduni	3.00±0.25	2.0±0.10	nd	nd	11
Kisukioni	2.80±0.40	nd	Present	nd	5
Ngonda	22.80±0.80	4.90±0.50	nd	nd	9
Kyamulendu	4.40±0.10	3.70±0.40	nd	nd	13
Silanga	30.80±1.20	4.30±0.10	nd	nd	5

nd = Not detected

It is generally assumed that DOC in potable waters is due to naturally occurring organic matter such as fulvic and humic acids, and tannins. Smaller organics are less likely to give rise to visible colour, since they do not contain chromophores that absorb in the visible region. Humic and fulvic acids are a heterogeneous mixture of organic acids, alcohols, amines, aromatics and aliphatics. They are large molecules that may contain many functional groups in close proximity and sometimes distant enough to behave as discrete entities. DOC concentrations in the present study were determined at 360 nm because it is generally assumed that much of the DOC in soft waters comes from humic substances which make up to 75% of the total DOC [5, 11] and have significant health effects. The regression equation (1) reliably predicts the levels of DOC in range 1.6-4.2 $g\ m^{-3}$. This relationship is similar to that observed from streams and rivers of the west coast of South Island, New Zealand where DOC was dominated by humic substances [5]. Faecal coliforms were detected in more sites during the wet season than during the dry season. During the wet season, faecal coliforms were detected in 11 sites while during the dry season they were detected only in two sites.

Table 2. Level of DOC and presence of faecal coliforms in wells and boreholes in Ngong Division, Kajiado district.

Site/Substance	DOC (g m^{-3})		Coliforms		Depth of well (m)
	Wet	Dry	Wet	Dry	
Banda	2.50±0.30	2.00±0.30	Present	nd	274
Nthiga	2.70±0.60	2.00±0.30	Present	nd	14
Ongata Rongai	3.00±0.20	2.10±0.40	nd	nd	11
Race Cource	3.10±0.30	2.70±0.50	Present	nd	37
Kiserian	2.40±0.50	3.00±0.30	Present	nd	305
Lolua	13.80±0.40	7.20±0.50	nd	nd	305
Quarry	3.00±0.30	4.20±0.40	nd	nd	9
Ngong town	2.40±0.50	2.00±0.40	nd	nd	9
Kiserian town	4.00±0.20	2.20±0.50	nd	nd	152
Karen	2.40±0.50	nd	nd	nd	46
Lewisa	2.70±0.40	2.40±0.60	nd	nd	5
Nyaga	nd	nd	nd	nd	17
Kikeni	nd	nd	nd	nd	9

nd = Not detected

Table 3. Level of DOC and presence of faecal coliforms in wells and boreholes in Kikuyu Division, Kiambu District.

Site/Substance	DOC (g m^{-3})		Coliforms		Depth of well (m)
	Wet	Dry	Wet	Dry	
Kikuyu town	2.20±0.40	nd	nd	nd	229
Sigona	2.70±0.70	2.10±0.20	nd	nd	244
Muguga	2.50±0.50	2.20±0.40	nd	nd	335
Zambezi	3.00±0.80	4.30±0.50	nd	nd	305
Wangige	2.80±0.20	2.80±0.20	nd	nd	21
Gikuni	4.20±0.20	3.10±0.10	nd	nd	24
Lower Kabete	5.20±0.10	7.20±0.20	nd	nd	11
Upper Kabete	2.45±0.40	nd	nd	nd	17
Kirangari	2.40±0.40	2.10±0.20	nd	nd	21
Ondiri	4.20±0.20	3.00±0.10	nd	nd	26
Thogoto	3.00±0.10	2.20±0.10	Present	nd	26
Alliance	16.80±0.45	4.60±0.30	Present	nd	21

nd = Not detected

In Kangundo Division, faecal coliforms were detected in 5 sites during the wet season and in 2 sites during the dry season. Both Ngong and Kikuyu Divisions had 4 and 2 sites, respectively with faecal coliforms during the wet season. No faecal coliforms were detected in sites located in these two Divisions during the dry season. The fate of faecal coliforms and other microbes in the subsurface is determined by their survival time and retention by soil particles. Both survival and retention times are largely determined by three factors: climate, soil properties, soil pH and organic matter. Climate controls two factors in determining microbial

survival time: temperature and rainfall. The survival time of microbes is prolonged at low temperature [9, 12].
Rainfall mobilizes previously retained microbes and greatly increases their transport to underground waters [13]. This explains why more faecal coliforms were detected in more sites during the dry season. In 10 out of the total number of 11 sites in which faecal coliforms were detected had DOC, although the faecal coliforms were not found in the sites with highest levels of DOC. This may be due to DOC having some substrate on which faecal coliforms may feed on. The fact that faecal coliforms were not necessarily detected in sites with the highest levels of DOC might be due to the different sources from where DOC originates. DOC mainly comes from dead animals and plants while faecal coliforms originate from faecal waste.

Faecal coliform bacteria were not detected in water from both Kenyatta University and Kabete Water Works apparently due to chlorination employed during treatment. Kenyatta University water was found to have both DOC and suspended organic matter. Suspended organic matter was observed as the residue left on a 0.45µm fibre glass filter. Two samples out of five contained DOC of 2.05 mg L^{-1} and 3.10 mg L^{-1}.

Conclusion

Groundwater pollution in the study area from human activities, measured by the nitrates and nitrites concentration was negligible [14] but the presence of high levels of DOC and faecal coliform bacteria in Kangundo Division during wet season suggests contamination of wells from the surface run-off rain water directly into the wells that are poorly constructed unlike in Ngong and Kikuyu Divisions where wells are well protected by concrete cone-shaped walls which prevent surface run-off and water spills from the wells from draining again into the wells when water is being drawn manually with buckets. The contamination of boreholes with faecal coliform bacteria at Banda and Kiserian in Ngong Division during wet season suggests contamination of underground water with a possibility of contact with municipal waste or any other industrial effluents.

It is, therefore, important to educate inhabitants about the contamination of the well or borehole water from the waste disposed in the neighbourhood; irrigation projects and industries that could lead to adverse health implications. The wells and boreholes need to be protected from outside contaminations. The present investigation forms a basis for awareness to the public regarding their environment and recommends regular water testing by the Water Department of the Ministry of Water and Natural Resources.

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