Original article

Chemical, physical, and microbiological characterstics of various sources of water in and around Addis Ababa

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Abstract: Every month, from November 1996 to October 1997, water samples from 18 different sites were collected. The samples belong to the following categories: reservoirs that supply Addis Abeba's tap water (Lakes Gefersa and Legadadi) city taps, city swimming pools, Ambo Mineral Water, rain water, Akaki and Bulbula Rivers and Lake Aba Samuel.

Four different physical variables (PH, Temperature, Total Dissolved Solids, and Conductivity) and concentration of 19 different cations, anions, and CO_2 were determined. The results revealed no health risk except the high concentration of Cr^{3+}, Cd^{2+}, Fe^{3+}, Pb^{2+}, Mn^{4+} and Nitrate in Akaki and Bulbula Rivers samples. The water from these rivers is not consumed by city residents although they are used by rural communities to the east and southeast of Addis Abeba. Similarly, the two swimming pools included in this study had high TDS,HCO_3^- and fluoride content as well as slightly increased Cd^{2+}, Pb^{2+} and Cu^{2+} levels. On the other hand, parasitological and bacteriological analyses revealed all sources were clean except Akaki, Bulbula and Aba Samuel. Infact these results suggest drinking waters of Addis Abeba are safe, while recreational waters of the city are acceptable for the purpose they serve. However, in view of polluted rivers flowing out of Addis Abeba and Lake Aba Samuel, methods of minimizing the health risks they pose are suggested. [*Ethiop. J. Health Dev.* 1999;13(3):239-246]

Introduction

Next to Oxygen, water is the most important substance for human existence(1). It is an essential nutrient, which also sustains agriculture, allows aquatic life, supports industry, produces hydroelectricity, permits aquatic transport, insures personal hygiene, maintains clean environment, and is used for sport as well as for recreation (2,3). Certainly, man gets the benefits listed above from the entire water resources of the world which is estimated to be 1.4 x 10^9 km^3 (4). However for the, most part, human existence depends on fresh water supply which is less than 1% of the water available on Planet earth (5).

The fresh water of the world is obtained from the annual precipitation of about 10^5 km^3 (6) out of which Ethiopia's yearly share is estimated to be 110km^3 (2). However, 75% of this water vanishes through the borders with neighboring countries (7) leaving behind 27.5km^3. On the other hand, since this water is not evenly distributed, arid and semiarid regions of the country are threatened by desertification(7). Hence, the need for methods of water impounding and conservation as practised by some regional governments of Ethiopia. This task becomes even more pressing as industrialization and development advances.

In addition to the process of desertification, pollution is also reducing the volume of safe fishing, irrigation, and drinking, water. For instance a USA report revealed that consumption of sea food

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of ground water to hazardous chemicals is increasing (9). Radioactive wastes discharged in the1950s in some Russian rivers are still contaminating the food chain (10). Furthermore, a review by Pruss (11) indicated that swimming in waters containing upto 30 CFU/100mL of E.coli and faecal products had led to increased morbidity and mortality(8). Likewise cancer mortality due to exposure

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streptococci caused gastroenteritis. Notice that there is a minimum level of cleanliness accepted for accidental swallowing and skin exposure let alone for consumption and other sensitive uses of water.

Ethiopia is no exception to excreta and organic pollutions mentioned above. It is proving hard to give up open air defecation inspite of the acute sense of embarrassment by those who practise it and its' condemnation by communities (12). Teka (13) had shown that in Ethiopia, water and excreta based diseases are on the rise. Household and other rubbish are thrown away with little, if any, regard to one's actions. It is common knowledge that several factories dump their dangerous waste into ditches and rivers. It is not possible to claim that this carelessness is restricted to organic waste either. While some effort is made to store or bury radioactive waste by some institutions, careless dumping can never be ruled out. In general apathy of offenders, behavioural tolerance of the community, lack of knowledge about consequences of pollution, and cultural insensitivity of the vast majority of the population to environmental degradation is an alarming phenomenon that demands urgent action. It is clear from the above that we should make a ceaseless effort to avoid chemical, microbial, etc. pollution of the environment in general and water resources in particular. In view of the above it is necessary to seek the basic physical, chemical, and microbial profile of Ethiopia's water resources in general. However, this paper focuses on the limited objective of compiling an annual chemical, bacteriological, and parasitilogical composition of some water resources in and around Addis Abeba. It is also a more extended version of an earlier investigation by Worku and Ejigu, 1994 (14) which was based on a single month's sample collection and never included microbial and parasitic analysis. Finaly, it tries to draw attention to water resources that are polluted by the city.

Methods

Sample collection: Every month, 18 different water samples were obtained from November 96 to October 97. The collection was made, from the following sites representing Addis Ababa's various water sources, namely, the two upstream reservoirs at Gefersa and Legedadi (both raw and treated waters), tap waters from various locations in the city, a mineral water bottled in Ethiopia, rain water, (roof-run-off from a house in Woreda 19 was collected after rain was allowed to clean the roof), two city rivers (Akaki and Bulbula) that serve as sources of drinking water for humans and animals living in rural areas east and southeast of the city, Lake Aba Samuel (a dam that receives most of the city's liquid waste), and two swimming pools in the city (Figure 1). For each water source, the sampling site was never changed.

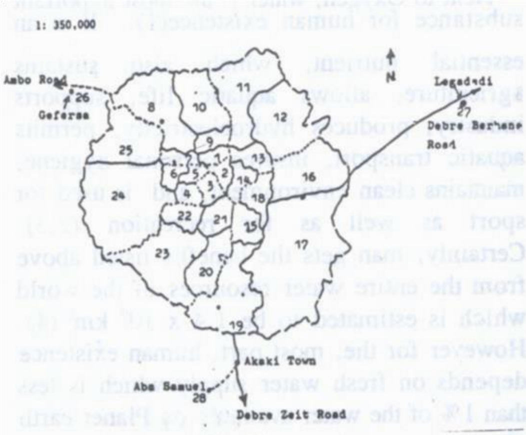

Figure 1: **Map of sample collection sites**

Note:
The numbers within Addis Ababa are code numbers of Weredas (Councills). The black dots are sampling sites. Ambo is 125km west of Addis Ababa.

All samples were collected by grab method. Reservoir samples were from Addis Ababa Water and Sewerage Authority's sampling taps. Ambo Mineral Water samples were collected at official sampling taps. Samples from swimming pools, city rivers, and Aba Samuel were surface waters. Water from domestic taps of various weredas were collected after discharging about a liter of water at every sampling site. Rain water was collected by a method stated above.

Methods on chemical and physical characteristics: Every month, a single 5L sample was collected per location in a plastic bottle thoroughly cleaned by detergent, hypochlorous acid, distilled water, and finally rinsed with deionized water. The samples were then filtered using Whatman's No 42 filter paper and stored at 4^oC until analysis was carried out. Temperature was taken at the time of sample collection. Information on the odour, taste, and colour of each sample was obtained from five water laboratory technicians. The pH was read on calibrated Beckman's 050pH meter. Conductivity (con.) was read on microprocessor LF 2000/C conductivity meter of GmbH W. Germany, which was calibrated using 10,25,50,75, and 100mM standard KCl solutions. Both Beckman's 050pH meter and LF 2000/C possess inbuilt programmes that calculate and display readout at 25^oC. The total dissolved solids (TDS) of a sample that was evaporated by a steam bath and dried at 105^oC was measured using an analytical balance.

The cations (Sodium, Potassium, Magnesium, Calcium, Iron, Cadmium, Chromium, Lead and Zinc) were determined by atomic absorption spectrometer (Varian SP-20) using their respective hollow cathode lamps (15). Carbondioxide and Bicarbonate were measured by titration using phenolphthalein and methyl orange indicators, respectively(16). Since bottles of Ambo Mineral Water were opened under atmospheric pressure and 10^{0}C, reported Carbondioxide content is nearer to what is available to the consumer and not the quantity bottled by the factory, i.e., minimum values are reported. Chloride was titrated by 10mM $AgNO_3$ to K_2CrO_4 endpoint(17). Fluoride was assayed by a specific ion selective electrode (18). Sulphate was determined as $BaSO_4$ particles in a turbid solution (19). Nitrate was estimated using Varian DMS 80 spectrophotometer set at two different wave lengths. The absorption at 220nm is for nitrate and organic nitrogen whereas the absorption at 275nm is only for the latter. Optical density due to nitrate was then obtained by subtracting double the reading at 275nm from the reading at 220nm(20).

Method on bacteriological characteristics: All microbial analyses were conducted within 48 hours of sample collection using portions of the 5L sample that were never subjected to Whatman's No. 42. Tests were conducted using 100mL of water aseptically filtered through a nitrocellulose filter (Gelman Sciences, Michigan, USA). The filters were then layered on endoagar. After 24 hours, the number of visible colonies were counted (21). Further tests were conducted on those membranes that had viable bacterial colonies. To do this, 10ml of Lauryl tryptose broth (35.6gm/L) was inoculated by about 10 viable colonies, and the mixture was incubated at 37^0 C for 24 hours. Those samples that displayed gas inclusion in tube inserts were then subjected to Brilliant Green Lactose broth at 37^oC for 24 hours and the presence of gas emission was checked. Final test to identify whether the organisms were E.coli or other Enterobacter species was done using Eosin methylene blue agar's confirmatory test (21,22).

Method on parasitological characteristics: Parasitological tests were conducted on samples of 100mL of water by modification of the method of Levine and Estenez (23). The samples were concentrated by centrifugation. Then one drop of the sediment was resuspended in one drop of 0.85% saline and an aliquot was applied to a slide. The preparation mentioned above was viewed under low power microscope for cyst or ova. At times iodine was added for detection of protozoan cysts.

Table 1: **Annual averages of physical and chemical characterisitcs of water samples collected from November 1996 to October 1997 from sites stated.**

	Sites									
Analyte	Akaki	Bulbula	Aba Samuel	W 17 Bole	Gefersa Raw	Gefersa Treated	Legedadi Raw	Legedadi Treat	Nefas Silk	W 18 Gulele
pH	7.64	7.54	7.67	7.47	7.12	7.16	7.37	7.44	7.43	7.7
T	6.00	8.25	18.67	18.75	17.25	16.33	17.75	16.83	16.83	17.5
Con	486.33	876.75	377.33	93.33	60.25	108.25	84.50	90.75	97.25	423.2
TDS	386.41	652.83	341.58	76.58	56.00	79.75	81.50	72.83	77.17	140.2
Na^{+}	35.75	50.10	32.08	2.23	2.33	2.29	2.27	2.24	2.26	6.55
K^{+}	15.35	26.70	8.13	1.68	1.42	1.07	2.30	1.64	1.64	1.63
Mg^{2+}	9.14	15.5	9.33	2.42	2.06	2.08	3.11	2.46	2.54	5.33
Ca^{2+}	41.83	53.17	36.08	10.28	5.62	12.35	11.00	9.87	10.83	15.5
Cr^{2+}	0.10	0.10	0.10	0.10	0.10	0.10	0.18	0.10	0.10	0.10
Cd^{2+}	0.10	0.10	1.93	0.10	0.10	0.10	0.10	0.10	0.23	0.10
Fe^{3+}	0.11	0.41	0.38	0.06	1.93	0.11	4.20	0.00	0.10	0.10
Pb^{2+}	0.10	0.10	0.10	0.10	0.10	0.10	0.18	0.09	0.10	0.10
Zn^{2+}	0.10	0.10	0.10	0.46	0.10	0.13	0.13	0.10	0.36	0.50
Cl^{-}	43.92	97.41	23.83	6.42	0.87	3.25	0.72	5.67	5.83	2.95
F^{-}	0.38	0.61	0.63	0.16	0.08	0.06	0.46	0.16	0.16	0.24
CO_2	22.78	24.3	12.6	4.58	5.58	4.17	4.92	4.00	4.55	5.67
HCO_3^{-}	212.08	255.25	179.08	38.33	27.33	20.50	42.42	36.58	36.58	79.25
NO_{3-}	2.45	10.96	22.28	2.93	2.41	1.20	3.66	2.90	2.81	9.38
SiO_2	23.25	28.67	34.00	10.08	11.50	6.83	15.08	10.25	9.92	27.58
$SO_{4=}$	7.07	29.08	8.50	2.81	5.06	24.5	8.12	2.20	3.85	1.09
HBO_2	0.33	1.15	0.41	0.42	0.39	0.34	0.50	0.72	0.26	0.36
Cu^{2+}	0.10	0.08	0.10	0.10	0.10	0.10	0.10	0.05	0.11	0.10
Mn^{4+}	0.10	0.58	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

(Table 1 continued)

	Sites								
Analyte	W 15 Kasanchis	W 5 Merkato	Ambo Raw	Ambo Treated	W 15 Hilton	W 21 Ghion	W 23 Makanisa	W 19 Rain	Normal Value
pH	7.41	7.19	6.41	5.82	8.0	8.56	7.22	6.33	6.5-8.5
T	8.08	17.75	31.0	22.0	35.50	27.42	19.0	12.8	-
Con	92.2	95.2	1664	1653.2	2938.8	1236.6	108.9	34.0	50-1500
TDS	74.4	74.1	1415.8	1406.9	2575	1016.2	82.1	27.6	1000
Na^{+}	2.25	2.18	222.31	244.27	807.08	291.2	10.58	0.21	200
K^{+}	1.63	1.32	32.36	30.91	13.74	7.05	1.69	0.66	-
Mg^{2+}	5.33	2.33	44.64	40.59	1.74	2.18	2.46	0.23	50
Ca^{2+}	15.5	10.48	72.36	64.91	4.58	8.17	8.72	3.76	75
Cr^{2+}	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.05
Cd^{2+}	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.005
Fe^{3+}	0.10	0.12	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Pb^{2+}	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.05
Zn^{2+}	0.50	3.22	0.10	0.10	0.10	0.10	0.68	1.11	5.00
Cl^{-}	2.95	5.50	30.55	33.91	47.35	26.58	7.35	1.03	250
F^{-}	0.24	0.11	0.69	0.70	22.54	7.43	0.15	0.03	1.5
CO_2	5.67	4.84	582	1730	33.6	7.00	5.85	6.14	6.5-8.5
HCO_3^{-}	79.25	28.08	1031.6	1029.27	1764.3	775.9	40.42	4.43	-
NO_{3-}	9.38	2.04	2.40	0.55	0.53	3.31	2.06	7.67	10
SiO_2	27.58	9.08	36.34	35.82	88.25	35.83	12.17	- -	-
$SO_{4=}$	1.09	7.92	0.86	0.83	53.58	26.58	1.56	2.80	400
HBO_2	0.36	0.28	0.79	0.98	1.38	0.63	0.26	0.37	-
Cu^{2+}	0.10	0.10	0.10	0.10	0.10	0.19	0.10	0.10	0.005
Mn^{4+}	0.10	0.10	0.16	0.24	0.10	0.10	0.10	0.10	0.10

Temperature (T) is in ^{0}C, Total dissolved solid (TDS) and concentrations are in mg/L, conductivit y (con) is in μ-mho/cm . The values given are means. Ssee References 24, 25 and 26 for normal values, conductivity of potable water is from Ref. 15 pages 2-43 to 2-48. W is wereda. -- not known

Table 2: **Annual mean of coliforms that were detected in sampling sites from November 96 to October 97.**

S ite	Aba Samuel	Akaki	Bulbula	(Gefersa Raw)	Legedadi (Raw)
Mean(EFU/100mL)	112	270	170	50	79

Data compilation and analysis: The chemical, physical and microbiological results were processed using the World Health Organisation's Epidemiological Computer Programme developed by CDC in 1994, i.e., Epi. info version 6.22 (Epi-6). The information collected included mean, SD, p-value, etc. The mean was based on 12 averages except for rain water which was from nine sample collections. Each average was done on triplicates of a single sample. Standard error of the mean of each average was < 5%.

Results

Chemical and physical characteristics: All filtered water samples were colourless. However, unfiltered water samples of Gefersa and Legadaddi were brownish yellow. None of the samples had any dectetable odour. Since Akaki, Bulbula, and Aba Samuel waters were polluted with excreta, their tastes was not determined. The raw Mineral Water had a blend of sour and bitter taste whereas the treated Mineral Water had Soda flavour. All the other samples were tasteless.

Table 1 presents chemical and physical characteristics of samples from 18 different localities. Measurements collected over 12 months were processed by Epi-6 and only the mean values are displayed. Notice, conductivity and total dissolved solid of two groups of water were very high compared to that of pure water : 1. Akaki River, Bulbula River, and Lake Aba Samuel; 2. The swimming pools of Hilton and Ghion as well as Ambo Mineral Water. Furthermore, the sodium content of the mineral water under investigation was also high (244mg/L) compared to WHO's guideline value of 200mg/L (24). On the other hand, lowest conductivity and lowest total dissolved solid were determined for rain water.

Table 3: **Number of Cysts or Ova detected in 100mL samples from Novermber 1996 to October 1997 from the sites stated**

	Sites & counts/100mL				
Species	Month	Aba Samuel	Akaki	Bulbula	Gefersa (Raw)
Entamoeba Coli	December’96	-	-	3	4
	January’97	1	5	-	2
	February	-	-	2	
	March	-	-	3	
	April	-	1	-	2
	May	-	-	2	
Etamoeba histolytica	November’96	-	3	1	
	December	-	3	-	
	January’97	-	4	3	
	February	-	2	-	
	March	-	8	-	
	April	-	2	-	
T. Trichuria	November’96	-	3	-	
	January’97	-	6	-	-

Bacteriological characteristics: Every month, for twelve months, triplicate tests were conducted for every sample. The observed, total colony forming units/100mL of E.coli and/or Enterobacter species are displayed in Table 2. All others (13 sample sites) except the five listed below gave results that were not detectable.

Parasitological characteristics: Every month, for twelve months, triplicate tests were conducted for every sample. No parasite ova or cyst was detected in treated water of Legedadi and Gefersa, tap waters of Addis Abeba, raw or treated mineral waters, swimming pools, or rain water of Addis Abeba. Parasites were seen only in samples and months indicated in table 3. Even for these sites, detections were not throughout the year but were observed for a few months (Table 3).

Discussion

During this study, no bacteriological or parasitological organisms were seen in samples of treated water of Legedadi, Gefersa, Addis Abeba taps, rain water, and mineral waters. The concentration of various analytes were also within the normal values accepted by WHO (24,25 & 26) although conductivity, TDS, Sodium, CO_2 , HCO_3^- concentration of the mineral waters were also high. Neverthless, the aformentioned TDS is within 150% of the normal value and is probably tolerated.

Equally, the high concentration of CO_2 and HCO_3^- is unlikely to pose any health risk since CO_2 toxicity, except in suffocation, is unknown (27). Similarly conductivity, TDS, HCO_3^- and fluoride

($\geq$7.43 mg/L) content of the swimming pools were high. However, they do not pose any health risk, since they are not used for drinking. It is clear from the above that drinking waters of Addis Abeba are safe for health, while recreational waters of the city are acceptable for the purpose they serve.

With the exception of Cr^{3+}, Cd^{2+}, Pb^{2+} and Fe^{3+} concentrations that were at $\geq$ 2 the normal values, the raw waters of Gefersa and Legedadi were within WHO's guideline values.

However, occasionally parasite ova/cyst were detected in samples from those sites. Their bacterial contamination which was at less than 100CFU/100mL but higher than the maximum permissible level of 10CFU/100mL poses health risk (26). On the other hand these coli forms might be from livestock excreta and, hence, pose little health risk, particularly to local immune inhabitants. It is clear from the above rigorous effort is needed to minimize the microbial contamination of waters flowing into Legedadi and Gefersa reservoirs. One way to achieve this would be to declare the environs of these water sources to be nature's reserve.

Except for Cr^{3+}, Cd^{2+}, Fe^{3+}, Pb^{2+}, Mn^{4+} and Nitrate contents all other chemicals tested in this study revealed low values for Akaki and Bulbula Rivers. Nevertheless the deleterious effect of these ions on health can not be underestimated. Likewise parasitic ova/cyst existed for most parts of the year in Akaki. Lower parasitic values that were seen in Bulbula might be attributed to the fact that samples were collected in rural area almost near the entry point of Bulbula to Aba Samuel whereas Akaki River's samples were from Saris Market to the East of Bhere-Tsege garden, i.e., one of the most polluted sections of the river. Aba Samuel samples were from the dam end of the lake, hence, parasite ova/cyst had time to settle to the bottom of the lake or adhere to the dense tuber vegetation that completely covered the lake. Further more, the rate of bulk water flow through the lake is low, hence, time is in favour of lower parasite burden of the water at the outlet of the dam. Lower parasite levels of the rivers that were registered from May to September can be attributed to the dilution effect of rain. All the same, the presence of bacteria at >100 CFU/100mL is indicative of faecal contamination making these waters a high health risk.

Inspite of the above, Akaki, Bulbula and Aba Samuel waters are used to grow vegetables that are sold in Zone 3 markets, to water animals, and as drinking water of rural communities outside Addis Abeba.

Recommendations

In view of the pollution stated earlier and economic significance of these waters, more effort should be made to teach the local community on methods of minimizing the deleterious effects of their water supply. One approach could be drinking water from wells dug a few meters away from these bodies of water, thus benefiting from ground filtration of the polluted water. Furthermore, awareness of hygenic handling of vegetables should be introduced. In addition, the following future actions may be considered; 1. Conduct organic analysis of these sites since factories are in the habit of releasing their effluents; 2. Encourage industries on alternative method of waste disposal; 3. Conduct skin test, kidney function test, stool examination, etc. in communities that depend on these water sources using a rural community between Akaki Town and Aba Samuel, that has access to clean well water, as control. Last but not least, there is a need to draw the attention of the Water and Sewerage Authority or all concerned to consider methods of minimizing faecal pollution of Akaki, Bulbula, and Aba Samuel.

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