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CHEMICAL AND BACTERIOLOGICAL STUDIES ON WATER OF VARIOUS SOURCES IN THE BENGHAZI AREA*

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Samples collected from different water sources were analysed for their major and minor chemical constituents. The values thus obtained were compared with their sources of collection. The major constituents in all the samples were found to be sodium, chloride, sulphate and bicarbonates. Large variations in the levels of the major constituents were encountered among the water samples collected from lake, wells and tap. Lake water contained lowest amounts while high quantity of major chemicals was found in the tap water of the Benghazi area. The levels of alkalinity, hardness, calcium, magnesium and potassium were comparatively less altered. Attempts were made to correlate the present findings with possible biological hazards. Bacteriological studies provide no indication for the presence of any pathogenic micro-organisms in water.

Key words: Environmental pollution, Water analysis, Benghazi water.

INTRODUCTION

The importance of water in the maintenance of life is now fully understood. The ecocycle of living organisms may greatly be influenced by certain physiochemical factors, such as temperature variation or water pollution. The introduction of various industrial projects, excessive use of toxic chemicals including fossil fuel and human intervention in the ecocycle have contributed to a large extent to the deteriorating effect on the natural environments of earth. To encounter the problems related to water pollution, accurate information on the quality of water is of fundamental importance. Such information may be utilized in pollution prevention and control or management of water resources. Sometimes immediate measures are required in respect of accidental discharges of pollutants.

Extensive studies have been made on waters of lakes [1,2,3], taps [4,5], rivers [6,7,8], wells [9,10,11] and springs [12,13] regarding their chemical composition, bacteriological status and extent of pollution, and their possible impact on health. Our previous report [14] provided the estimates of various chemical constituents of air particulates (aerosol) of the Benghazi area. The present study deals with the quantitative analysis of natural water collected from two lakes located at the Green mountains (Jabl-e-Akhdar), wells and taps of the Benghazi area which is situated in the Mediterranean region and has moderate rainfall in the winter season. The possible effects of certain minor and major constituents of water on health are also discussed.

MATERIALS AND METHODS

The site of collection, source of water and month in which the water samples were collected are given in Table 1. One liter polyethylene containers were used for each

Table 1. Details of samples collected from the Benghazi area and lakes of Green Mountain (Jabal-e-Akhdar), Libya.

Sample No.	Site of collection	Source	Month
1.	El-Gubah	Lake	December
2.	El-Gaigab	"	December
3.	El-Sabri	Well	January
4.	Hawari Form	"	February
5.	El-Sabri	"	April
6.	Hawari Form	"	May
7.	Bohdima	Tap	March
8.	University Hostel	"	January
9.	El-Mufawas	"	March
10.	El-Fouhed	"	May

*Summer Temperature : Max. 40^{o}, extreme 51^{o}
Winter Temperature : Min. 10^{o}, extreme 1^{o}
Rainfall 11" (267mm).

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sample collection. For microbiological studies, samples were collected according to the guidelines provided by World Health Organisation [18].

All the chemicals employed in the preparation of reagents were of analytical grade. Physiochemical analysis were performed for each sample in triplicate and the average value was recorded. pH and conductivity measurements were made immediately after collection using a digital pH meter and conductometer Model D-8120, Weilheim LBR 40. A sample of 100 ml of water was evaporated to dryness in a porcelain dish and constant weight recorded for total solid residue. Standard spectrophotometric, flame photometric and titrimetric procedures were employed for the evaluation of major water constituents [15-17]. The hardness of water was determined by the measurement of total calcium and magnesium ion concentration with the sequestering agent, sodium ethylene-diaminetetracetate (EDTA).

A double beam atomic absorption spectrophotometer, Pye Unicam Model SP-1900, equipped with air-acetylene flame, was used for the estimation of trace elements [19,20]. Standard procedure was employed for the sampling of water for bacteriological analysis [16]. The work on bacteriological examination involved counting of the bacterial population and identification of individual bacterium.

RESULTS AND DISCUSSION

Table 2, 3 and 4 provide the chemical composition of the lake and Benghazi water from wells and taps. Statistical analysis of the data has been carried out and the estimated values of the various components of water have been reported as mean (lake samples 1-2), and as mean ± S.D. (wells and tape samples 3-10). The results of bacteriological studies are given in Table 5. Fig. 1 illustrates the pattern of compositional variations among the samples of lakes, wells and taps.

pH. The pH of lake water ranges from 7.70 to 7.80 with a mean of 7.77 whereas that of the water from wells ranges from 7.60 to 8.10 with a mean of 7.72. The pH of the tapwater shows similar range (7.41–7.75) as lakes and wells with a minimal difference.

Usually the pH of any body water varies within the narrow range between 7 and 9 because of the existence of natural buffering mechanism associated with atmospheric carbon dioxide and bicarbonate ions. However, in a number of highly industrialized places, the pH of lakes and rivers has dropped to as much as 3.00. This drop has been attributed to sulphuric and nitric acids in the air and nitrogen oxide in the atmosphere emitted by the burning of fossil fuels [21]. The increased acidity has been suspected to induce some ecological effect such as increases in the amount of calcium and other minerals due to leaching from the soil, death of fish and reduction in forest growth [22]. Since the atmosphere of Benghazi and its neighbouring areas are more or less free from industrial pollution, the pH of water in these areas falls within the normal limit.

Table 2. Estimated values of major and minor constitutents in water samples collected from two of Jabal-e-Akhdar, Libya (ppm).

S. No.	Components	Estimated values (Samples) 1	2	Mean	WHO guideline value of drinking water (ppm)
1.	Conductivity (μS/cm)	550	750	650	
2.	pH	7.70	7.80	7.77	6.5-8.5
3.	Total solid	520.0	573.0	546.5	1000
4.	Hardness	160.0	144.0	152.0	500
5.	Total alkalinity	199.0	175.5	187.2	
6.	Bicarbonate	186.9	151.5	172.2	
7.	Carbonate	12.0	24.0	18.0	
8.	Sodium	42.0	49.0	45.5	200
9.	Potassium	2.0	7.0	4.2	
10.	Calcium	57.75	64.1	60.9	
11.	Magnesium	35.0	38.9	36.9	
12.	Chloride	75.0	98.0	86.5	250
13.	Sulphate	30.9	104.9	67.9	400
14.	Ammonia	0.16	0.08	0.12	
15.	Nitrogen	0.13	0.07	0.10	
16.	Nitrate	0.22	0.41	0.31	
17.	Nitrite	tr.	0.01	0.05	10
18.	Zinc	tr.	0.04	0.18	5
19.	Lead	0.60	tr.	0.30	0.05
20.	Manganese	10.0	10.0	10.0	0.1

*tr. = trace

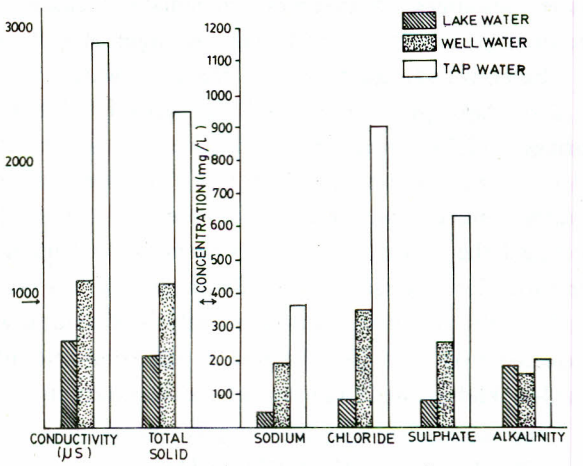

Fig. 1. Variations in major chemical constitutents in different water samples.

Table 3. Estimated values of major and minor constitutents in water samples collected from the underground wells of Benghazi (ppm).

S. No.	Components	Estimated values (samples)				Mean ± S.D*	WHO guideline value for drinking water (ppm)
		3	4	5	6		
1.	Conductivity (μS/cm)	900	1110	1700	1500	1300 ± 363.4	
2.	pH	8.1	7.6	7.6	7.6	7.72 ± 0.25	6.5-8.5
3.	Total solids	650.0	1040.0	1540.0	1080.0	1077.00 ± 364.3	1000
4.	Hardness	180.0	240.0	202.6	220.0	212.00 ± 25.6	500
5.	Total alkalnity	61.5	234.6	118.6	234.6	162.33 ± 86.6	
6.	Bicarbonate	56.6	220.0	110.6	214.6	150.29 ± 80.3	
7.	Carbonate	4.9	14.4	8.0	20.0	11.82 ± 6.7	
8.	Sodium	130.4	195.0	270.0	190.0	196.00 ± 57.2	200
9.	Potassium	4.8	8.9	7.0	8.0	7.18 ± 1.8	
10.	Calcium	22.1	42.1	42.1	45.0	37.82 ± 10.6	
11.	Magnesium	10.6	51.3	49.2	43.5	41.15 ± 20.4	
12.	Chloride	258.0	318.0	506.0	320.0	350.50 ± 107.6	250
13.	Sulphate	133.7	288.0	174.9	421.8	254.62 ± 129.1	400
14.	Ammonia	0.06	0.02	0.04	0.08	0.05 ± 0.03	
15.	Nitrogen	0.05	0.02	0.03	0.07	0.42 ± 0.4	
16.	Nitrite	6.38	2.6	3.5	0.00	3.120 ± 2.6	10
17.	Zinc	0.33	0.06	3.05	0.33	0.19 ± 1.7	5
18.	Copper	0.08	0.05	0.52	0.00	0.045 ± 0.3	
19.	Lead	0.30	1.10	0.30	0.45	0.54 ± 0.4	0.05
20.	Manganese	0.02	0.02	0.0	0.0	0.01 ± 0.01	

*S.D = Standard deviation

Conductivity and total solids. Conductivity of lakes water ranges from 550 to 750 μS/cm with a mean of 650, whereas this range in underground waters is 900-1700 μS/cm with a mean of 1300. The range of conductivities in tap water was found to be the highest. Thus well waters show two fold and tap water four to fivefold increase in conductance as compared to the water collected from lakes. As conductivity of water is considered to be directly proportional to the amounts of total solid contents, it is an easy and fast index to establish the extent of water pollution by solid contents i.e. lower the conductance, fewer are the contaminants in water. Usually single distilled water may have a conductivity of 20 μS/cm whereas double and triple distilled waters are expected to have a conductance of 2.5 and 1.5 μS/cm respectively (23).

The amount of total solids in lake water ranged from 520-73 with a mean of 546.5 mg/l which is comparable to the permissible level provided by World Health Organization (500 mg/l) for drinking water. The ranges of total solids in water collected form wells and taps in Benghazi were higher i.e. from 650 to 1540 with a mean of 1077 mg/l and from 2270 to 2480 mg/l with a mean of 2422.5 mg/l respectively, thus the concentration of total solid pollutants in wells and taps exceeded the international safe limits (i.e. 1000 mg/l).

Sodium, potassium, chloride and sulphates. It is evident from the resutls (Tables 2-4) that the bulk of total solids in water is mostly due to the accumulation of sodium, chloride and sulphates. The ranges of sodium ion in lake, well and tap waters were 42-49, 130-270 mg/l and 220-490 mg/l with a mean of 45.5, 196.0 ± 57.2 and 363.7 ± 136.3 mg/l respectively. The ranges of chloride ions in the lake, well and tap waters are 75-98, 258-506 and 776-1037 mg/l with the mean of 86.50,350.5 ± 107.6 and 901.7 ± 107.2 mg/l respectively. The concentration of potassium ions in all the water sample is very low, being lowest in the lake and highest in the tap waters. The sodium, chloride and sulphate content of these waters is well within the WHO guideline values.

Fairly high concentration of electrolyte in tap water may pose serious health problems to those who suffer from heart disease, hypertension and other conditions requiring

Table 4. Estimated values of major and minor constituents in water samples collected from the taps of Benghazi (ppm).

S.	Components	Estimated values (samples)				Mean ± S.D*	WHO guideline value for drinking water (ppm)
		7	8	9	10		
1.	Conductivity	2900	3000	3000	2950	2962.50 ± 47.9	
2.	pH	7.75	7.4	7.6	7.55	7.50 ± 0.2	6.5-8.5
3.	Total solids	2470.0	2480.0	2420.0	2320.0	2422.50 ± 73.2	1000
4.	Hardness	312.0	226.0	217.2	212.0	242.00 ± 47.2	500
5.	Total alkalinity	200.8	204.0	206.6	215.6	206.50 ± 5.9	
6.	Bicarbonate	183.3	196.0	193.4	202.0	193.43 ± 8.2	
7.	Carbonate	18.5	8.0	13.2	12.0	12.91 ± 4.3	
8.	Sodium	470.0	220.0	490.0	275.0	363.75 ± 136.3	200
9.	Potassium	15.5	17.0	17.0	14.0	15.88 ± 1.4	
10.	Calcium	69.0	70.0	74.1	76.0	72.30 ± 3.3	
11.	Magnesium	41.4	44.2	52.8	47.4	46.51 ± 4.9	
12.	Chloride	910.0	1037.0	884.0	776.0	901.75 ± 107.2	250
13.	Sulphate	718.0	617.2	718.1	673.2	681.65 ± 47.9	400
14.	Ammonia	0.04	0.02	0.04	0.04	0.03 ± 0.01	
15.	Nitrogen	0.03	0.02	0.03	0.03	0.28 ± 0.3	
16.	Nitrate	6.7	9.3	0.00	10.9	6.734 ± 4.8	10
17.	Zinc	0.14	0.24	4.6	0.11	1.289 ± 2.2	5
18.	Copper	0.02	0.08	0.03	0.05	0.04 ± 0.03	
19.	Lead	0.65	0.15	0.15	0.65	0.40 ± 0.39	0.05
20.	Manganese	0.01	0.02	0.00	0.02	0.01 ± 0.01	0.01

*S.D = Standard deviation

Table 5. Bacteriological data for water samples collected from different sources of Benghazi area.

Sample No.	Source	Counts/100 ml	Micro-organism present
1.	Lake	6.4×10^6	(a) *Achromabacter eutrophus* (b) *Flavobacterium ohcraceum* (c) *Pseudomonas fluorescenslique faciens.*
2.	Lake	6.2×10^6	(a) and (b)
3.	Well	3.3×10^8	(a)
4.	Well	2.9×10^7	(a) and (e) *Micrococcus aquatilis*
5.	Well	6.6×10^7	(g) *Aspergillus sp.*
6.	Well	4.0×10^6	(b)
7.	Tap	1.6×10^8	(a) and (d) *Staphylococcus epidermidis*
8.	Tap	1.0×10^8	(a) (b) and (f) *Bacillus mycoides*
9.	Tap	1.4×10^8	(a) and (f)
10.	Tap	4.0×10^7	(d)

low salt intake such as dropsy, renal disease, liver cirrhosis, obesity and several pregnancy conditions [24]. New born babies may have added problems since a premature kidney has limited ability to concentrate or to dilute water during homeostasis [25]. It is quite probable that few of these major constituents in Benghazi water migh have been originated from the sea through seepage of water.

The range of sulphate ions is found to be extremely variable among the samples of water collected from different sources. Lake water contains 30.9 mg/l to 104.9 mg/l of sulphate ion with the mean of 67.9 mg/l. The range of sulphate ion in well waters is from 133.7 to 421.8 with a mean of 254.6 ± 129.1 whereas the tap water contains the highest concentration ranging from 617.2 to 718.1 mg/l with the mean of 681.6 ± 47.9. The permissible level for drinking water as recommended by WHO is 400 mg/l. In this respect, lake water may be considered to be the best suited water for human drinking. Tap water distributed in Benghazi is overloaded with sulphate ions. Such overloading of sulphates in water supplies may cause devastating effects on human physiology. An increased concentration of sulphates in the drinking water has been reported to be the cause of large scale diarrhoea in the local population of two central asian villages [26].

Total alkalinity, bicarbonates, carbonates, magnesium and calcium. The ranges of total alkalinity presented as

$CaCO_3$ vary slightly from sample to sample. Greater variations are seen in the samples collected from wells. Such variations may be due to the two different seasons when the samples were obtained from the wells. The differences in the mean value of total alkalinity is reflected in the levels of bicarbonates, carbonates, magnesium and calcium. The presence of high amounts of calcium with phosphorous depletion may cause certain disorders such as renal calculi, rickets and gallstone formation. The pathogenesis of such diseases which are common in Benghazi may be related to the type of water consumed by these patients.

Minor constituents and trace elements. The ranges of nitrogenous matter (NH_3, NO_3 and NO_2) are relatively low indicating lesser organic pollution in water. The range of nitrates in lakes is from 0.22 to 0.41 with mean of 0.31. This level in wells and tap waters is slightly higher (31.2 and 6.74 mg/l respectively). Nitrite is present in all waters in trace quantities.

Nitrates as such do not create any health problem but when converted by certain bacteria into nitrites in the body may produce methemoglobinemia, especially in infants [27].

The evaluation of trace elements such as zinc, copper, lead and manganese was carried out by means of atomic absorption spectrophotometry. Lake water contains lower levels of trace elements as compared to well and tap water with the exception of lead and manganese. Although the mandatory limit of 0.05 mg/l of lead is considered physiologically safe, it may deliver toxic effects when consumed for several weeks at concentrations of 8-10 mg/l. Concentration of lead in the range of 15 mg/l over the same period may be lethal. It damages the kidney, liver or brain and causes mental retardation [28]. The ranges of zinc, copper and manganese in all water samples may be considered as "permissible".

Bacteriological studies. The results of bacteriological examinations of the water samples are presented in Table 5. As many as seven types of bacteria were detected in various samples. They were (a) *Achromabacter eutrophus,* (b) *Flavabacterium ochrocaum,* (c) *Pseudomonas fluorescenslique faciens,* (d) *Staphylococcus epidermidis,* (e) *Micrococcus aquatilis,* (f) *Bacillus mycoides,* (g) *Aspergillus sp.* Large variability in the total counts as well as growth of the individual bacteria among samples may be due to different local hygienic conditions of various locations from where the water was collected. No pathogenic bacterium, molds or fungi were detected in the water samples. WHO has provided guidelines for the bacterial counts of pathogenic organisms in drinking water [18].

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