

Groundwater quality of north-east Libya

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Abstract: The quality of groundwater was assessed to their suitability for drinking at six places of north-east Libya viz. El-Marj, Albayda, Shahat, Susa, Ras al-Hilal and Derna, during November, 2003 to March, 2004, by determining their physicochemical parameters (17 parameters) and water quality index (15 parameters). The temperatures of water samples averaged 15.1°C, pH values were alkaline and dissolved oxygen values were in safe ranges. Electrical conductivity, total dissolved solids and hardness of water at all places except Susa were within the standard limits. Alkalinity of well water at all six places exceeded, and chlorine and chloride (except Susa) were within the desirable limits set for them. Fluoride and nitrate contaminations of well water were not observed, and only very low values of phosphorus, manganese, chromium, iron and zinc were recorded. Copper in well water was generally high, and at Susa and Ras al-Hilal, it exceeded the desirable limit. Parametric ratios showed that all parameters studied except those of pH, dissolved oxygen, alkalinity and total chlorine originated from sources different from that of hardness. Water quality index (WQI) revealed that well water of Albayda and Shahat were good for drinking and were only slightly polluted, whereas those of El-Marj, Ras al-Hilal and Derna were moderately polluted. However, the well water of Susa was excessively polluted and was unsuitable for drinking. Suitable suggestions were made to improve the quality of groundwater of N.E. Libya.

Key words: Desirable limit, North-east Libya, Parametric ratio, Physicochemical parameters, Pollution, Water quality index, Well water.

Introduction

The physicochemical parameters and water quality index of groundwater of six places viz. El-Marj, Albayda, Shahat, Susa, Ras al-Hilal and Derna (Fig. 1) of north-east Libya were determined from November, 2003 to March, 2004, to assess their suitability for drinking purposes. Elevated places like El-Marj, Albayda and Shahat, the main tourist centres of Libya, are located in Jebel al-Akdar (Green mountains), whereas Susa, Ras al-Hilal and Derna are situated on its foothills. The main occupation of the people residing here is agriculture and they heavily depend on the groundwater for drinking, domestic, livestock and agricultural purposes. The periodic monitoring of groundwater quality is necessary to safeguard its long term sustainability (Adak and Purohit, 2003) and water quality index is an indicator revealing the composite influence of a number of water quality parameters which are significant for specific beneficial uses (Horton, 1965).

Materials and Methods

Study area: The groundwater samples were collected from the wells of six places in north-east Libya. Their names, elevations, types of soil, locality of wells, depth of wells and uses of well water are given in Table 1.

Soils of El-Marj, Albayda and Shahat were humus rich clayed carbonate mixture called 'Rendzinas'. The soils of El-Marj and Albayda were red and that of Shahat was black in colour. It belonged to intrazonal holiothogenic group of soil that was alkaline with a total nitrogen range from 0.04% to 0.20%; 1.35% clayed residues and 1.34% calcium carbonate. The soils of Susa, Ras al-Hilal and Derna were 'Red ferrosialithic' also

known as terra rossa. It was a soil forming rock made up of clayed residues of limestone that was red in colour. It was alkaline with low nitrogen (0.13%) and high calcium, magnesium and iron contents. Organic matter of surface soil was around 1.67% but this percentage decreased with increasing depth (Nair *et al.*, 1996).

Analysis of well water: Well water samples without any air bubbles were collected in polythene bottles as per standard procedure. The date and time of collection were recorded and samples were analysed for 17 parameters. Temperature, electrical conductivity and total dissolved solids of the water were measured on the spot itself using Hanna autoranging microprocessor EC/TDS/°C meter, and pH by Beckman pH meter. The other parameters of water were analysed in the laboratory. Total alkalinity, total hardness and chloride were analysed following the procedures of APHA (1989) using Hanna freshwater analysis kit. The remaining parameters of water were analysed using Hanna multiparameter bench photometer. The parameters studied and methods employed (given in brackets) are as follows: a) Dissolved oxygen (azide modified winkler), b) Total chlorine (EPA, DPD), c) Fluoride (SPADNS), d) Nitrate (cadmium reduction), e) Phosphorus (amino acid), f) Manganese (periodate oxidation), g) Chromium (diphenyl carbohydrazide), h) Copper (EPA, bicinchoninate), i) Iron (EPA, phenantroline), and j) Zinc (zincon). Parametric ratio (Srinivas *et al.*, 2000) was calculated using the values of different water parameters, using hardness of water as a comparator.

Water quality index (WQI): Water quality index of well water was calculated following the procedures and equations given by Horton (1965), Ott (1978), Tiwari and Mishra (1985) and Kaur *et*

Table – 1: Information on the places of well water collection, north-east Libya

Name of place	Elevation (m)	Type of soil	Locality of well	Depth of well (m)	Use of well water
El-Marj	340	Rendzinas	Farm	248	Drinking, domestic, livestock, agriculture
Albayda	600	Rendzinas	Residential	300	Drinking and domestic
Shahat	625	Rendzinas	Residential	310	Drinking and domestic
Susa	90	Red ferrosialithic	Farm	42	Livestock, agriculture
Ras al-Hilal	40	Red ferrosialithic	Residential	200	Drinking, domestic, livestock, agriculture
Derna	26	Red ferrosialithic	Residential	200	Drinking, domestic, livestock, agriculture

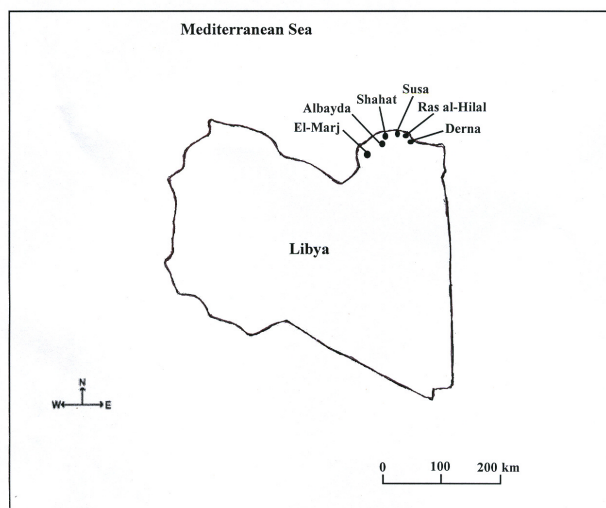


Fig. 1: Map of Libya showing the places of north-east Libya from where well waters were collected for analyses.

al. (2001) with slight modifications. To calculate WQI, fifteen parameters of water were selected. These were pH, dissolved oxygen (DO), total dissolved solids (TDS), total hardness (TH), total alkalinity (TA), total chlorine (TC), chloride (Cl), fluoride (F), nitrate (NO₃), phosphorus (P), manganese (Mn), Chromium (Cr), Copper (Cu), iron (Fe) and zinc (Zn).

The unit weights (Wi) of all factors were calculated (Table 2) based on the equation

$$W_i \propto \frac{1}{V_i} \text{ or } W_i = \frac{K}{V_i} \dots\dots\dots(1)$$

Where Wi = Unit weight of the chemical factor
 Vi = Standard (desirable) limits
 K = Constant of proportionality

Value of 'K' was calculated as

$$K = \frac{1}{\sum_{i=1}^{15} \frac{1}{V_i}} \dots\dots\dots(2)$$

The word unit weight implies relative significance of each of the factor in overall water quality and is dependent on the standard (desirable) limits in drinking water as prescribed for pH, TDS,

TH, Cl, F, NO₃, Fe, Zn by WHO (1984), for DO, TC, P, Mn by Renn, (1970) and for Cr, Cu by BIS, (1983) (Table 2). Factors having low permissible limits can harm the quality of water to a large extent even on a slight increase and such factors have high weightings. On the other hand factors which have higher permissible limits have low weightings (Kaur et al., 2001).

Regarding rating scale, each factor had been assigned a rating value (Vr) to calculate WQI. The values fell between 0 and 100. To assign rating value to a factor, range of its concentration in water was divided into five intervals. The rating Vr = 0 implied that chemical factor exceeded standard (desirable) limit and water was polluted, while Vr = 100 implied that chemical factor had the most desirable value and the water was clean. The other ratings falling between these two extremes were Vr = 40, Vr = 60 and Vr = 80, representing intermediate conditions of water (Table 3).

To calculate WQI, the products of rating (Vr) and unit weights (Wi) of all 15 factors were summated

$$WQI = \sum V_r \times W_i \dots\dots\dots(3)$$

Water quality index was calculated in this way for the well water of all six places. WQI falling within the range of 0-39.99 stood for severely polluted water; between 40-59.99 for excessively polluted water; between 60-79.99 for moderately polluted water; between 80-99.99 for slightly polluted water, and 100 for absolutely clean water (Table 4).

Results and Discussion

The physicochemical factors of well water analysed during November, 2003 to March, 2004 in six places in north-east Libya, together with the average value of each factor, its S.D. and coefficient of variation (C.V) are presented in Table 5.

The water temperatures averaged 15.1°C and there were only very little variations in temperature between stations. This could be attributed to rainy and winter seasons that prevailed during the period of investigation. The pH of water samples of all stations was alkaline and it ranged from 7.8 to 8.7. The desirable limit for pH is 7.0-8.5 which is a safe range for drinking (WHO, 1984). In the present study the pH of well waters of Shahat (8.6) and Ras al-Hilal (8.7) exceeded this limit. Generally pH of ground water is influenced by geology of catchment area and buffering capacity of water (Weber and

Table – 2: Water quality factors: their standards and assigned unit weights.

Sl.No.	Water quality factors*	Standards (Desirable limits) (Vi)	Unit weights (Wi)
1	pH ¹	<7.0-8.5>	0.0020
2	Dissolved oxygen ²	>6.0 ppm	0.0025
3	Total dissolved solids (TDS) ¹	<1000 ppm	0.000015
4	Total hardness ¹	<500 ppm	0.000030
5	Total alkalinity ¹	<120 ppm	0.00013
6	Total chlorine ²	<0.50 ppm	0.0300
7	Chloride ¹	<250 ppm	0.000060
8	Fluoride ¹	<1.50 ppm	0.0100
9	Nitrate ¹	< 50 ppm	0.00030
10	Phosphorus ²	< 0.10 ppm	0.1503
11	Manganese ²	< 0.10 ppm	0.1503
12	Chromium ³	< 0.05 ppm	0.3006
13	Copper ³	< 0.05 ppm	0.3006
14	Iron ¹	< 0.30 ppm	0.0500
15	Zinc ¹	< 5.00 ppm	0.0030

Source : ¹WHO (1984), ² Renn (1970), ³ BIS (1983)

Table – 3: Rating values for different factors to calculate WQI

Sl.No.	Factors *	Ranges				
1	pH	7.0 - 8.5	8.6 - 8.7	8.8-8.9	9.0-9.2	> 9.2
			6.8 - 6.9	6.7-6.8	6.5-6.7	< 6.5
2	Dissolved oxygen	> 6.0	5.1-6.0	4.1-5.0	3.1-4.1	< 3.0
3	Total dissolved solids (TDS)	0-250	251-500	501-750	751-1000	> 1000
4	Total hardness	0-125	126-250	251-375	376-500	> 500
5	Total alkalinity	21-50	51-70	71-90	91-120	> 120
6	Total Chlorine	0-0.13	0.14-0.26	0.27-0.39	0.40-0.50	> 0.50
7	Chloride	0-60	61-120	121-180	181-250	> 250
8	Fluoride	0-0.4	0.41-0.80	0.81-1.20	1.21-1.50	> 1.50
9	Nitrate	0-13	14-26	27-39	40-50	> 50
10	Phosphorus	0-0.025	0.026-0.050	0.051-0.075	0.076-0.1	> 0.1
11	Manganese	0-0.025	0.026-0.050	0.051-0.075	0.076-0.1	> 0.1
12	Chromium	0-0.012	0.013-0.024	0.025-0.036	0.037-0.050	> 0.05
13	Copper	0-0.012	0.013-0.024	0.025-0.036	0.037-0.050	> 0.05
14	Iron	0-0.07	0.08-0.14	0.15-0.21	0.22-0.30	> 0.30
15	Zinc	0-1.25	1.26-2.50	2.51-3.75	3.76-5.00	> 5
	Ratings (Vr)	100	80	60	40	0

* All factors except pH are in ppm

Table – 4: Classification of water quality*.

WQI	Water quality	Designation
100	Absolutely clean	Class I a
80-99.99	Slightly polluted	Class I b
60-79.99	Moderately polluted	Class II
40-59.99	Excessively polluted	Class III a
0-39.99	Severely polluted	Class III b

* Reference: Kaur *et al.*, (2001)

Stun, 1963). Higher pH reduces the germicidal potentiality of chlorine and induces the formation of toxic trihalomethanes

(Trivedy and Goel, 1986). According to European economic community report (Indirabai and George, 2002), the permissible standard for drinking water for dissolved oxygen (DO) is 5ppm and above, and Renn (1970) postulated 6 ppm and above as the standard desirable limit of oxygen for water, but this value varies depending upon water temperature and the partial pressure of oxygen in its gas phase. The DO of well water at all six places were above 7ppm. The high level of oxygen could be due to the mixing of rain water rich in oxygen with the ground water.

The electrical conductivity, total dissolved solids and total hardness of the well waters of all places except that of

Table – 5: Physicochemical characteristics of well water of north-east Libya.

S.No	Places	Water temperature (°C)	pH	Dissolved oxygen (ppm)	E.C. (m.mho/cm)	T.D.S. (ppm)	Total hardness (ppm)	Alkalinity (ppm)	Total chlorine (ppm)	Chloride (ppm)	Fluoride (ppm)	Nitrate (ppm)	Phosphorus (ppm)	Manganese (ppm)	Chromium (ppm)	Copper (ppm)	Iron (ppm)	Zinc (ppm)
1	El-Marj	15.2	8.2	7.6	1039	832	291	246	0.03	190	0.10	15.50	0.09	0.00	0.00	0.046	0.05	0.32
2	Albayda	15.0	8.5	8.3	600	488	255	234	0.06	80	0.11	7.09	0.05	0.00	0.00	0.036	0.02	0.17
3	Shahat	15.0	8.6	8.4	589	487	210	240	0.06	60	0.01	21.21	0.00	0.00	0.00	0.036	0.07	0.27
4	Susa	15.0	7.8	7.0	5760	4610	813	270	0.08	1540	0.87	42.09	0.09	0.00	0.00	0.262	0.12	0.00
5	Ras al-Hilal	15.1	8.7	8.3	981	784	330	255	0.08	160	0.19	5.76	0.03	0.00	0.07	0.089	0.04	0.00
6	Derna	15.0	8.4	8.5	900	720	252	213	0.05	160	0.15	21.26	0.02	0.30	0.006	0.011	0.05	0.00
	Average	15.1	8.4	8.02	1644.83	1320.17	358.50	243	0.06	365	0.24	18.65	0.04	0.05	0.002	0.085	0.06	0.13
	S.D.	0.08	0.34	0.59	2021.92	1618.37	226.29	19.35	0.02	577.85	0.32	13.18	0.03	0.12	0.003	0.091	0.03	0.15
	C.V.	0.56	4.02	7.36	122.92	122.59	63.12	7.96	31.67	158.32	132.35	70.67	75	240	154.55	112.05	58.62	115.75

Susa were within the standard desirable limits set for natural waters by WHO (1984) (EC: 1400 μ mho/cm; TDS: 1000ppm; total hardness: 500ppm). In Susa, the values of these parameters exceeded far higher than the desirable limits. Srinivas *et al.*, (2000) opined that the higher value of EC in groundwater is due to the high dissolved solids which may subscribe to the conductivity and has a direct bearing on the percentage of total solids. High TDS may be due to groundwater pollution by waste waters which is discharged into pits, ponds and lagoons and migrate down the water table (Rani *et al.*, 2003). This may be true in the case of the well water of Susa, where large heaps of cattle and human wastes were seen dumped around the area where the well was located. The main sources of hardness in water are sedentary rocks, seepage and run-off from soils and hardness mainly originates in areas with thick top soil and limestone formation (Sawyer and McCarty, 1967), a condition that prevailed in Susa and to some extent in Ras al-Hilal, where the soils were red ferrosialithic. Renn (1970) stated that hardness in groundwater is also due to the addition of calcium and magnesium ions to a natural water system as it passes through soils and rocks containing large amounts of these elements in mineral deposits.

Alkalinity in water provides an idea of natural salts present in it. The standard desirable limit of alkalinity in potable water is 120ppm (WHO, 1984) and the values of this parameter in well waters of all six places exceeded this limit. The cause of alkalinity is the minerals which dissolve in water from soil.

The various ionic species that contribute to alkalinity include bicarbonate, hydroxide, phosphate, borate and organic acids and these factors are characteristic of the source of water and natural processes taking place at any given time (Sharma, 2004). The presence of chlorine in concentrations above 0.5ppm in natural waters should be considered evidence of pollution (Renn, 1970). In the present study the total chlorine in well waters ranged from 0.03ppm in El-Marj to 0.08ppm in Susa and Ras al-Hilal. The permissible limit for chloride in drinking water is 250ppm (WHO, 1984). Except Susa (1540ppm), the chloride of well waters of all other places were within the prescribed desirable limit. The well waters of elevated places like Albayda (80ppm) and Shahat (60ppm) recorded the minimum concentrations of chloride. The presence of chloride in large amounts in the well water of Susa may be an indication of pollution from seawater, since it is located very near to the coast.

Fluoride and nitrate of well waters were within the desirable limits set for them (1.5ppm for fluoride and 50ppm for nitrate) by WHO (1984). Fluoride with 0.6 to 1.2ppm is regarded as an essential constituent of drinking water mainly because of its role in prevention of dental caries (McClure, 1970). High nitrate values in ground water are possibly due to organic and sewage pollution and in the present study, the well water of only Susa (42.09ppm) recorded higher nitrate content.

The values of phosphorus, iron and zinc recorded in the well waters were not of any concern and were within the prescribed limits set for them by WHO (1984), Renn (1970) and

Table – 6: Parametric ratios between hardness and other parameters of ground waters of north-east Libya.

Sl. No.	Parametric ratio	Average	SD	C.V.
1.	pH/H	0.0234	0.0015	6.42
2.	DO/H	0.0224	0.0026	11.65
3.	TDS/H	3.6825	7.1518	194.21
4.	Alk/H	0.6778	0.0855	12.61
5.	Chlorine/H	0.000167	0.000088	52.69
6.	Chloride/H	1.0181	2.5536	250.82
7.	Fluoride/H	0.00067	0.00144	211.04
8.	NO ₃ /H	0.0520	0.0582	111.92
9.	P/H	0.000112	0.000133	118.75
10.	Mn/H	0.000139	0.000530	381.29
11.	Cr/H	0.0000555	0.0000133	238.35
12.	Cu/H	0.000237	0.000402	169.62
13.	Fe/H	0.000167	0.000133	79.64
14.	Zn/H	0.000363	0.000663	182.64

Table – 7: Water quality index (WQI) of well waters of different places of north-east Libya.

Sl.No.	Places	WQI	Designation	Inference
1.	El-Marj	72.90	Class II	Moderately polluted
2.	Albayda	87.94	Class Ib	Slightly polluted
3.	Shahat	84.90	Class Ib	Slightly polluted
4.	Susa	59.46	Class IIIa	Excessively polluted
5.	Ras al-Hilal	66.86	Class II	Moderately polluted
6.	Derna	78.92	Class II	Moderately polluted

BIS (1983). Traces of manganese and chromium were detected only in the well water of Derna. However, the value of copper recorded in the well waters of Susa (0.262ppm) and Ras al-Hilal (0.089ppm) exceeded the desirable limit (0.05ppm) (BIS, 1983), and the value of the same recorded in the well water of El-Marj (0.046ppm) was almost near to the permissible limit. The values of copper recorded in the present study were higher than the values recorded for the same in the well waters of Benghazi, situated on the western side of Jebel al-Akdar .

To assess the origin of sources, the parametric ratios between hardness of water with other parameters were tabulated and the results are presented in Table 6. Ratios of TDS, chloride, fluoride, nitrate, phosphorus, manganese, chromium, copper, iron and zinc in relation to hardness of waters had high co-efficient of variation values when compared with the C.V. value of hardness (63.12). This suggests that all the above factors originated from sources different from that of hardness.

The water quality index (WQI) of well waters of six places in north-east Libya together with their designations and quality of water are presented in Table 7. The well waters of Albayda (WQI: 87.94) and Shahat (WQI: 84.90) were slightly polluted and were good for drinking. Except for alkalinity, all other parameters studied in these two places were well within their standard desirable limits. Moderately polluted well waters were located in El-Marj (WQI: 72.90), Ras al-Hilal (WQI: 66.86) and Derna (WQI: 78.92) and they require suitable treatments such as filtration, chlorination, alum treatment, aeration, neutralization, softening and chemical precipitation, to minimize contamination and make them fit for drinking. To achieve this, water reservoirs can be built in the areas where the wells are located and water from the wells can be pumped into these reservoirs for suitable treatments before releasing them for human consumption. The well water of Susa (WQI: 59.46), however, was excessively polluted and was not potable. The water was much degraded and was unsafe for public health and it is strongly recommended that people should not be allowed to drink water from this well as a precautionary measure.

There is an increasing awareness among the residents of north-east Libya to maintain the well waters at their highest quality and purity levels and it is hoped that the present study may prove to be an useful tool in maintaining the water at the desired levels for different beneficial uses of the people residing there.

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