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Assessment of Groundwater Quality in Al-Buraimi, Sultanate of Oman

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Abstract

The suitability of groundwater quality of 21 wells perfectly located at the rural areas surrounding Al-Buraimi governorate in Sultanate of Oman was assessed for drinking purpose depending on the various water quality parameters. Standard techniques for physicochemical analysis of groundwater samples were used. The outcome of analysis performed shows the subsequent concentration ranges: pH (8.12-8.5), EC (240-877 μS.cm^{-1}), T.H (9-341.3 mg.L^{-1}), TDS (208-338 mg.L^{-1}), T.A (47.8-164.4 mg.L^{-1}), F^-(0-0.1 mg.L^{-1}), Cl^- (16.9-207.4 mg.L^{-1}), HCO_3^- (48-183 mg.L^{-1}), Ca^{2+} (5.9-26.6 mg.L^{-1}), and Mg^{2+} (10.6-207.4 mg.L^{-1}). The vast majority of the samples analyzed were under the policies set by both national (OS, 8/2012) and international (WHO, 2011) bodies for drinking water. Assessment of groundwater samples from numerous parameters implies that groundwater practically in most part of the study area is chemically suitable for drinking purpose.

1. Introduction

The Concern of access to potable water is very important. In developed countries, people may not put quite a lot of interest into the source of their own water. In many First World Nations, citizens can turn on a tap for fresh, potable water, which may also be enriched with elements like fluoride for health. In developing countries, however, a large proportion of the population does not have access to safe water. Yet 884 million individuals around the world live without improved water supply and 2.5 billion people still lack usage of ameliorated sanitation, including 1.2 billion who are deprived of a simple latrine at all [1] (WHO, 2008). The World Health Organization (WHO) estimates that 88% of diarrheal disease is actually caused by unsafe water, substandard sanitation and poor cleanliness. As a result, more than 4,500 children die every day by diarrhea and other diseases. For each and every child that dies, numerous others, including older children along with adults, suffer from poor health (WHO, 2008). In country such as Oman with extremely restricted water assets, excessive use of water results in deteriorating quality simply because there are fewer resources to diminish the concentration of substances hazardous to human health, to fruitful activities and to the environment in general. Alternatively, control of water quality may well lessen the amount of concerns (for instance via treatment procedures that permit the recycling of waste water); or simply it can worsen it, insofar as inadequate water quality generates incentives for raising tension on cleaner. Oman is located in the southeast of Arabian Peninsula and is actually bordered by the United Arab Emirates, Saudi Arabia, Republic of Yemen, Golf of Oman and Arabian Sea (Fig. 1). Oman has an arid climate, with an average rainfall of less than 200 mm/year [2]. Groundwater is the primary water source presenting 92% of the overall renewable water resources. Agriculture is the main consumer of waters accounting for 87% of renewable water recourses [2]. Dispersal of freshwater sources is actually unequal all over Sultanate of Oman along with its availableness which is now rare day-after-day on account of inhabitant expansions as well as assorted Omani activities.

Even without the fresh surface drinking water resources, groundwater is definitely used to meet up with the particular need exerted by several areas. Practically all groundwater is composed of minerals transported in solution, the kind as well as the concentration of which frequently rely on the surface and subsurface surroundings, degree of groundwater mobility and source of groundwater [3]. Precipitation is relatively free of minerals until eventually it comes in touch with several components found in the soils. Due to the solvent power of water, minerals are dissolved and brought into an aqueous solution while the water transfers throughout the aquifer. The cation along with anion concentrations rely upon the actual solubility of the minerals found in the formation, the time duration of water in contact with the rocks and the quantity of dissolved carbon dioxide within water [3]. Typically the chemical degeneration of the ground water varies according to numerous factors, for instance interaction with solid phases, residence time regarding groundwater, seepage of polluted river water, combining of groundwater with pockets of saline water in addition to anthropogenic impacts [3]]. The deterioration of quality is normally causing health risks and death of human being, livestock and demise of marine life existence, cropfailure in addition to loss of aesthetics [3].

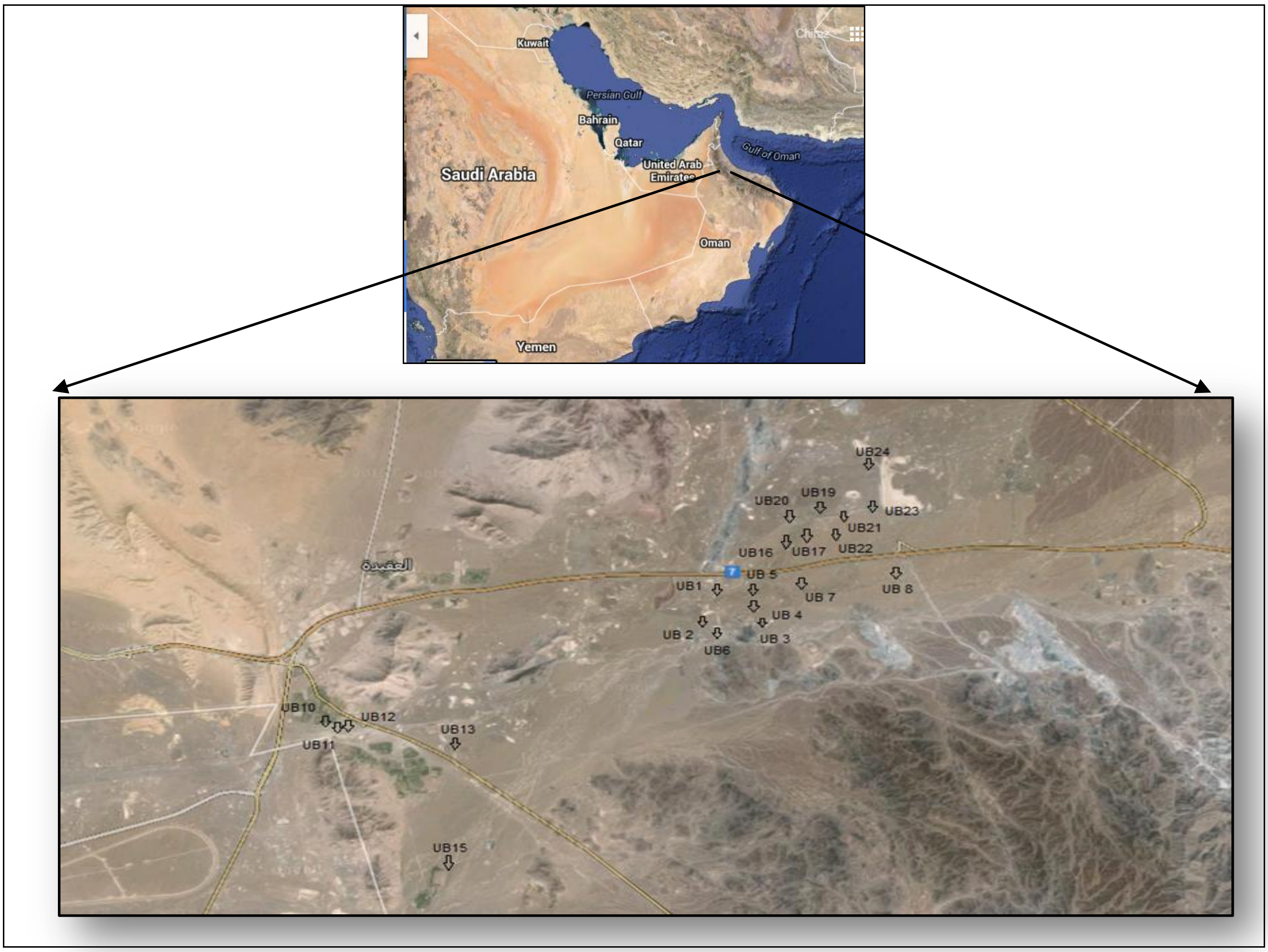
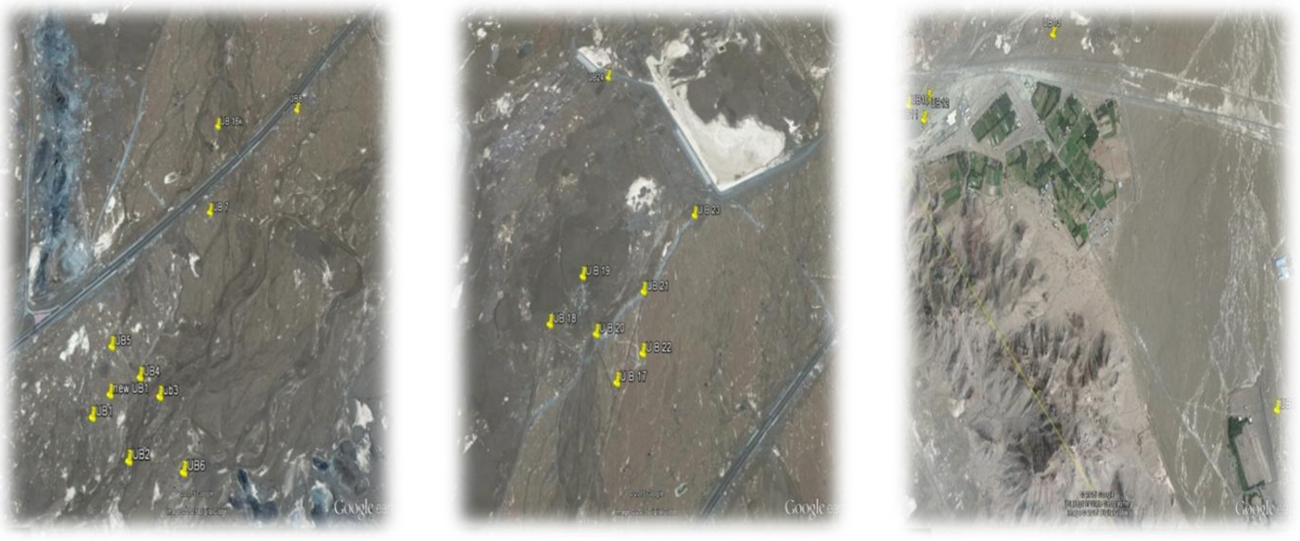


Figure 1: Al-Buraimi Governorate in Sultanate of Oman

To comprehend the geochemistry of Buraimi groundwater and to evaluate the entire physicochemical encounters in the examined area is absolutely essential simply because fresh water resources are uneven all through Sultanate of Oman plus the fresh water supply is getting rare day by day as a result of inhabitants expansion and diversified Omani activities. In the lack of fresh surface water resources, groundwater is definitely exploited to satisfy the need exerted through numerous areas. Al-Burimi governorate lies between the latitude 24°15’03” N and longitude 55°47’35” E and covering an area of 120 km². In order to understand the quality of drinking water supply in Al-Buraimi Governorate in Sultanate of Oman, physico-chemical characteristics were studied and analyzed. This paper presents findings on various Al-Buraimi groundwater parameters, such as water pH, conductivity, total alkalinity, total hardness, total dissolved solids, calcium, magnesium, chlorides, and fluorides...were studied and compared with National Drinking Water Quality Standard of Sultanate of Oman and WHO water quality guidelines.

2. Study Area

The study area, involves 21 wells spread on two areas: high spring and low spring, with productivity reaching (16000 m^3/day). The study area lies between the latitude24°15’03” N and longitude 55°47’35” E and covering an area of 120 km^2 (Fig. 2). The study area falls in the North West district of Sultanate of Oman. The average annual precipitation is around 36 mm and its climate is essentially arid. The aquifer is recharged by direct infiltration of precipitation, the main source of groundwater recharge. The average annual temperature varies from 20°C to 50°C.



(a) **(b)** **(c)**

Figure 2: (a),(b) and (c) Location map of sampling wells (Al-Buraimi, Oman)

3. Materials and methods

Several groundwater samples (Bore and open wells) were collected from the study area pre and post monsoon season respectively. Figures 2 and 3 show the locations of the 21 groundwater samples wells (Table. 1).

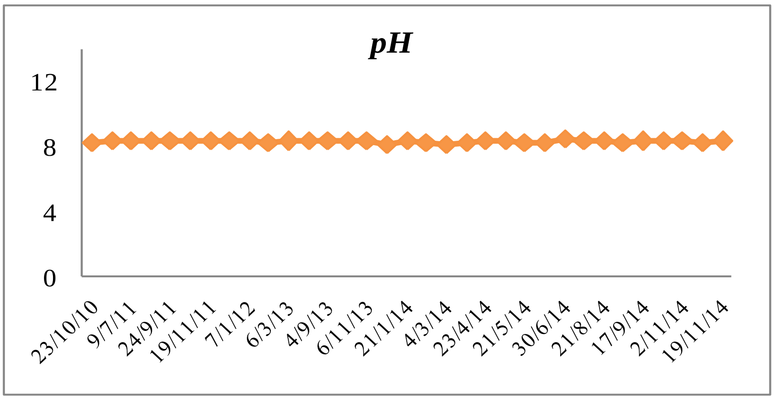


Figure 3: Potential of hydrogen of one of the studied wells (UB1)

The collection, preservation and chemical analysis for major ions of water samples were made, standard methods given by the EPA Method. The ionic constituents Ca^{2+}, Mg^{2+}, Cl^-, CO_3^{2-}, HCO_3^-, and $F^-$and the non-ionic constituents pH, Electrical conductivity (EC), Total dissolved solids (TDS) Total alkalinity (TA) and Total hardness (TH) were determined for these groundwater samples are shown in Table 2. Groundwater samples from 21 bore wells (Table. 1) of the unconfined aquifer were collected in duplicate in new pre-cleaned polypropylene bottles (450 mL capacity) every day in the morning time (8 am to 11 am). Before collecting water samples, water was pumped out from bore wells for about 3 min to remove stagnant groundwater. The physical parameters measured and recorded in the field are color, taste, odor, temperature, EC (using conductivity meter) and pH (using pH meter). Groundwater samples collected were colorless, odorless. All samples were stored at 4^{0}C.

Table 1: Sources of water (Al-Buraimi groundwater sampling wells)

Well code	Well name	Source of water
02/687	UB1	Buraimi Ground water
02/686	UB2	
02/685	UB3	
02/684	UB4	
02/683	UB5	
02/682	UB6	
02/681	UB7	
02/680	UB8	
02/689	UB10	
-	UB11	
-	UB12	
-	UB13	
02/381	UB15	
-	UB16	
-	UB17	
-	UB19	
-	UB20	
-	UB21	
-	UB22	
-	UB23	
-	UB24	

Table 2: Different analytical methods used to determine selected parameters (APHA, 2000)

Parameter	Instrumentation	Method
Acidity (pH)	Thermo (pHmeter)	EPA-(O.S. 199)
Electrical conductivity (EC)	Thermo (ECmeter)	EPA (O.S. 199)
Total hardness (T.H)	Na_2EDTA Titrimetric Method (digital burette)	EPA- (O.S.19)
Calcium (Ca^{2+})	Na_2EDTA Titrimetric Method (digital burette)	EPA-(O.S.19)
Magnesium (Mg^{2+})	Na_2EDTA Titrimetric Method (digital burette)	EPA(O.S.19)
Bicarbonate (HCO_3^-)	HCL Titrimetric Method (digital burette)	EPA
Carbonate (CO_3^{-2})	HCL Titrimetric Method (digital burette)	EPA
Chloride (Cl^-)	$AgNO_3$Titrimetric Method(digitalburette)	EPA- (O.S. 21)
Fluoride (F^-)	F^- meter	EPA- (O.S.17)

4. Results and discussion

The physico-chemical parameters of the groundwater supply in Al-Buraimi governorate is given in Table 3. The results are then compared with National Drinking Water Quality Standards (OS,8/2012) of Oman and WHO guideline value for drinking water (Table. 4) .

4.1. pH

The pH is of concern when chemical properties of groundwater are being investigated. Indeed low pH value may inhibit the growth of microorganisms [4].The reported pH values revealed that results were found to vary from 8.12 to 8.5, which indicates the slight alkaline nature of groundwater of the study area (Fig. 3).

These values comply with the Omani Standards (OS,8/2012) and as per the (WHO, 2011) standards (Table. 4), all the samples fall within the recommended limit (6.5-8.5) for human intake and irrigation. pH values are commonly changed by the existence of organic and inorganic solutes collectively with the reaction of Carbon dioxide [5]. One of the primary objectives in managing pH is to generate water that diminishes corrosion or incrustation. These kinds of operations; which lead to significant harm to the water supply models; outcome from complicated interactions involving pH and additional variables that include dissolved solids, dissolved gases, hardness alkalinity and temperature [6].The pH of groundwater could be diminished through organic acids from decaying vegetation or through dissolution of sulfide minerals [7].

Table 3: Five-year-average quality of Ground water in all Al-Buraimi wells

Parameter	**UB1**	**UB2**	**UB3**	**UB4**	**UB5**	**UB6**	**UB7**	**UB8**	**UB10**	**UB11**	**UB12**
pH	8.3	8.3	8.3	8.4	8.3	8.3	8.3	8.4	8.2	8.3	8.3
E.C.	387	425.3	447.7	378.1	415.9	496.1	360.5	335.2	482.1	531.3	432.2
T.D.S	251.8	276.4	291	245.7	269.5	322.3	234.3	210.5	313.4	345.3	281.1
F^-	0	0.045	0.1	0	0	0.1	0.1	0	0.1	0.1	0.1
Cl^-	43.5	51.6	55.8	41.9	49	54.3	40.5	37.1	59.5	69.5	51.5
C.H $_{\text{as CaCO3}}$	128	121.6	128.5	120.8	127.1	135.4	122.8	112.3	133.7	135.8	130.8
N.C.H$_{\text{asCaCO3}}$	34	21.7	28.1	27.8	34.7	12.3	31.7	17.1	44.6	45.7	29
T.H. $_{\text{as CaCO3}}$	161.1	134	148.9	142.7	158	144.2	141.4	125.4	174.6	178.5	153.5
Ca H. $_{\text{asCACO3}}$	26.8	29.4	37.6	25.6	34.7	39.6	25.4	23.2	37.5	39.9	31.4
Ca^{2+}	10.7	11.8	15.4	11.2	12.4	18	12.4	9.3	15	16	13
Mg^{2+}	32.2	25.1	26.7	28.1	29.6	25.1	36.2	33.1	51.1	59.8	45.1
B.C.A $_{\text{asCaCO3}}$	115.9	102.6	116.2	107.8	114.4	123.6	111.8	101.2	1222.6	123.3	118.9
C.A.$_{\text{as CaCO3}}$	12.2	19	12.4	13	12.8	11	12.7	11.7	11.1	12.5	14.4
H.A. $_{\text{as CaCO3}}$	0	0	0	0	0	0	0	0	0	0	0
M.O.A$_{\text{asCaCO3}}$	128	121.6	128.5	120.8	127.1	135.4	122.9	112.1	133.7	134.8	130.8
P.P.A $_{\text{as CaCO3}}$	6.1	9.5	6.2	6.5	6.4	5.5	5.7	5.8	5.5	6.3	6
NO_2^-	0.01	0.007	-	0.009	0.004	0.009	0.004	0.005	0.008	0.029	0.009
NO_3^-	8.44	9.01	8.88	7.27	7.68	10.4	3	5.64	11.33	19.9	9.95
K^+	1.7	2.4	2.2	1.75	1.85	2.57	1.7	1.7	2.3	2.75	2.6
Na^+	12.7	22.7	24.5	15.8	14.7	35.1	11.8	12.6	-	25.7	23.8

E.C: uS/cm at 25°C. All values, except pH are in mg.L^{-1}

Table 4: Omani Drinking Water Standard (Omani Standard No.8/2012) and the WHO Guidelines

Parameter	**UB13**	**UB15**	**UB16**	**UB17**	**UB19**	**UB20**	**UB21**	**UB22**	**UB23**	**UB24**
pH	8.3	8.4	8.3	8.3	8.3	8.4	8.4	8.3	8.4	8.3
E.C.	418	804.2	382.4	351.6	443.9	401.6	401.6	303	249.3	472.7
T.D.S	271.7	522.7	248.6	228.5	289.1	261.1	261.1	197.5	162	307.2
F^-	0.1	0.1	0	0	0	0	0	0	0	0
Cl^-	52.8	174.5	39.9	37.4	44.6	42.8	42.8	33.4	24.5	53.2
C.H $_{\text{as CaCO3}}$	128.3	125.7	46.3	126.6	148.8	137	137	49.7	90.3	125.3
N.C.H $_{\text{asCaCO3}}$	22.3	38.1	25.8	24.4	43.9	31.1	31.1	16.2	24.9	59.4
T.H. $_{\text{as CaCO3}}$	254.1	151.1	156.5	151.6	192.7	168.6	168.6	120.3	106.9	172.8
Ca H. $_{\text{as CACO3}}$	31.5	46.5	34.6	24.4	31.1	37.4	37.4	20.9	15.3	29.9
Ca^{2+}	12.7	18.6	13.6	10.8	13	12.5	12.5	9.6	0	0
Mg^{2+}	47.9	147.5	35.5	32.8	41.4	35.7	35.7	29.5	24.5	53.2
B.C.A $_{\text{as CaCO3}}$	113.9	108.6	126.7	124.4	117.4	138.8	126.7	100.1	79.5	109.1
C.A. $_{\text{as CaCO3}}$	14.4	25.6	10.3	9.3	9.2	10	10.3	7.9	10.8	16.2
H.A. $_{\text{as CaCO3}}$	0	0	0	0	0	0	0	0	0	0
M.O.A$_{\text{asCaCO3}}$	128.3	125.7	137	133.7	127.4	148.8	137	107.5	90.3	125.3
P.P.A $_{\text{as CaCO3}}$	7.2	12.8	5.2	4.6	4.4	5	5.2	4	5.4	8.1
NO_2^-	0.009	-	0.003	0.003	0.003	-	-	0.003	0.003	-
NO_3^-	7.28	5.66	6.3	7.06	3.44	-	3.44	3.82	5.1	8.15
K^+	1.9	-	1.5	-	1.8	1.6	-	1.2	1.6	1.6
Na^+	-	37.3	12	10.3	-	-	-	-	-	12.4

Table 4: Omani Drinking Water Standard (Omani Standard No.8/2012) and the WHO Guidelines

Parameter	Permissible limit	Max Allowable Concentration	WHO (2011)
pH	6.5	9	6.5-8.5
EC (μS.cm^{-1})			300-750
Ca^{+2} (mg.L^{-1})	-	-	-
Mg^{+2} (mg.L^{-1})	-	30 if sulphate ≥ 250 150 if sulphate ≤ 250	-
TH (mg.L^{-1}) as $CaCO_3$	$\leq$200	500	80-120
HCO_3^- (mg.L^{-1})	-	-	300
Cl^- (mg.L^{-1})	$\leq$250	600	250
Na^+ (mg.L^{-1})	$\leq$200	400	200
TA (mg.L^{-1}) as $CaCO_3$	-	-	200
F^-	0.6-0.8 for desalinated water	1.5	2
TDS (mg.L^{-1})	120-600	1000	755

4.2. Electrical Conductivity

EC has been used as a criterion for the classification of drinking and irrigation waters [8]. E.C. values are ranged from 240 to 877 μS.cm^{-1} (Fig. 4). According to WHO 2011 guidelines, the permissible limit of E.C.is 300-750 μS.cm^{-1}, higher values were noticed in third of the samples.

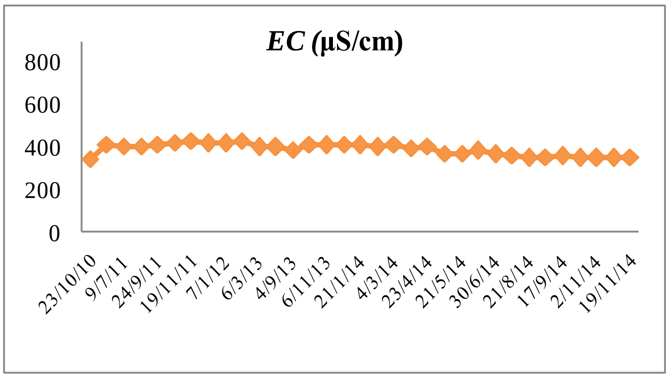


Figure 4: Electrical Conductivity of one of the studied wells (UB1)

A Few samples exceeded the desirable limit for E.C. (500 μS.cm^{-1}). The higher E.C. may cause a gastrointestinal irritation in human beings [9]. Usually the large variation in E.C. is mainly attributed to geochemical process like ion exchange, reverse exchange, evaporation silicate weathering, rock water interaction, sulfate reduction and oxidation processes [10]. In the study area, arid climate, evaporation rate and nutrient enrichment may be responsible for the enrichment of E.C. Higher electrical conductance in water is attributed to high salinity and mineral contents the presence of ions such as Na^+, Ca^{2+}, Mg^{2+}, F^-, Cl^-, NO_3^-, PO_4^{3-}, CO_3^{2-} and HCO_3^- contribute to salinity of Al-Buraimi groundwater.

4.3. Total Dissolved Solids

TDS approximated by residue on evaporation approach fluctuate in the range of 208-338 mg.L^{-1}. As per TDS distinction, 100% of the wells are fresh water (TDS < 1000 mg.L^{-1}) [9]. Solids amount didn't surpass the permissible limit of 600 mg.L^{-1} as per Omani Standards and 1000 mg.L^{-1} as per WHO standards (Table. 4). The term Total Dissolved Solids points primarily to the inorganic substances that are dissolved in water. TDS are composed of inorganic salts and small amounts of organic matter dissolved in water. It demonstrates the amount of minerals that are current in water in dissociated form. The consequences of TDS on ingesting water quality rely on the amount of its specific elements. Substantial hardness, taste, mineral deposition and corrosion are typical attributes of tremendously mineralized water [6]. Health side effects connected with the consumption of TDS in drinking water are not readily obtainable, and no health-based gridline value is suggested. Nevertheless, a guideline value of 1000 $mg.L^{-1}$ has been set up, based on taste factors. Water with particularly reduced concentrations of TDS could also be inappropriate because of its flat, insipid taste [11]. It has been reported [12] that TDS might reduce the hydraulic conductivity of irrigated area and that growing concerns are met as total dissolved solids content in water surpasses 480 $mg.L^{-1}$. TDS in water differ significantly in diverse geological territories due to distinctions in the solubility of minerals by (WHO 2011). Since groundwater transfers and remains for a prolonged time along its flow route, boost in total dissolved concentrations and main ions ordinarily takes place [6]. Substantial TDS value demonstrates extended residence time interval of water. TDS content is commonly the principal factor that restricts or maybe ascertains the utilization of groundwater for any kind of purposes (Table. 5). The investigation of samples for the seasons has revealed that there does exist an overall propensity of stableness and steadiness of TDS.

Table 5: Groundwater classification using total dissolved solids (TDS) [6]

Class	TDS $mg.L^{-1}$
Fresh	0-1000
Brackish	1000-10000
Saline	10000-100000
Brine	>100000

4.4. Calcium

Ca^{2+} is one of the most frequent constituents found in natural waters starting from 0 to several hundred milligrams per liter. Ca^{2+} induces hardness in water and incrustation in boilers. The demand for calcium is more significant during childhood, embrionario development, pregnancy and lactation. Epidemiological, animal and clinical studies suggest that an inverse connection is obtainable between Ca intake and occurrence of osteoporosis. A diet that is fortified in Calcium could help reduce the rate of age-related bone loss and hip fractures, notably amongst adult women [11]. The content of calcium during summer and winter seasons in study area ranges between (5.9-26.6 $mg.L^{-1}$) (Table. 3), results show very low levels of calcium, the values are well below the maximum permissible limit of Omani Standard No.8/2012 guideline. The desirable limit for Ca^{2+} for drinking water is specified as 75 $mg.L^{-1}$ (WHO 2011). As per standards the groundwater from this area is safe to use. Natural water sources typically contain concentrations of up to 10 $mg.L^{-1}$for calcium. The taste threshold for the Ca^{2+} is in the range 100-300 $mg.L^{-1}$, depending on the associated ions, but higher concentrations are acceptable to consumers [13]. The major source of Ca^{2+} in the groundwater is due to the ion exchange of minerals from the study area rocks. Further, this may also be due to the presence of $CaCO_3$, $CaSO_4$, $CaMg(CO_3)_2$ minerals and soils by water. Bower relates the presence of Ca^{2+} in groundwater to the occurrence of sedimentary sandstone as well as aragonite bearing minerals from sedimentary rocks [6].

4.5. Magnesium

Mg^{2+} concentrations are higher in the groundwater samples of the study area than Ca^{2+} concentrations, varying from (10.6-207.4 $mg.L^{-1}$) but aren't fully within the maximum limits of drinking water quality (30 $mg.L^{-1}$ if sulfate ratio is > 250 $mg.L^{-1}$ and 150 $mg.L^{-1}$ if sulfate ratio is < 250 $mg.L^{-1}$). The spatiotemporal pattern of magnesium is illustrated in Table 3. It can be observed from the table that magnesium concentration in the groundwater from 21 wells is acceptable and suitable for domestic applications (WHO, 2011), according to WHO 2006 the desirable value of $Mg^{2+}$is 50 $mg.L^{-1}$ [14] Mg^{2+} may probably have been delivered from the same source as Ca^{2+}. Calcium and magnesium in AFLAJ waters in the different regions of Oman are supplied by the weathering of carbonates, silicates and evaporate dissolution [2]. The prolonged agriculture activities prevailing in some study areas may also directly or indirectly affect mineral dissolution in groundwater [8]. Ca^{2+} and Mg^{2+} are both essential minerals for living organisms. Both of them occur in all kind of natural water with Mg^{2+} concentration generally lower than Ca^{2+} [5]. An average adult ingests as much as 480 mg of magnesium daily; excess amounts are quickly expelled by the body. No upper limit has been set for this metal in drinking water. Estimated daily intakes of 2.3 and 52.1 mg of magnesium in -soft and hard- water areas have been reported, based on adults drinking 2 L of water per day [13].

4.6. Chloride

Chloride and sodium are among the ions that are of concern in terms of specific ion toxicity. It was reported that they can accumulate in the plant needle (leaves) [4]. Chloride content is known to be low [15]; however noticeable increase in its concentration may indicate pollution from groundwater sources. The taste threshold of the chloride ion in water is dependent on the associated cation. Taste thresholds for sodium chloride and calcium chloride in water are in the range of 200 to 300 mg.L^{-1} [13]. The taste of Coffee is affected if it is made with water having a chloride concentration of 400 mg.L^{-1} as sodium chloride or 530 mg.L^{-1} as calcium chloride [16]. However, consumers can become accustomed to concentrations in excess of 250 mg.L^{-1}. Cl$^-$ content in the present study was found in the range of 16.9 to 207.4 mg.L^{-1} (Table. 3) (Fig. 5).

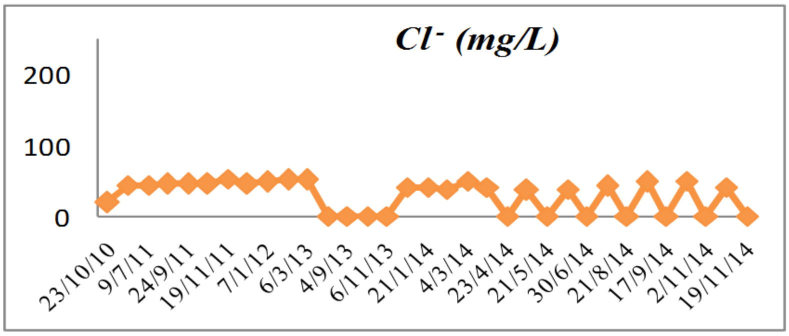


Figure 5: Chloride of one of the studied wells (UB1)

The desirable limit of Cl$^-$ is specified as 250 mg.L^{-1} as per WHO 2011 and 100% of the samples are well below the maximum permissible limit. Chlorides are harmless at low levels, chloride concentrations higher than 200 mg.L^{-1} are considered to be risky for human consumption and causes unpleasant taste of water [5] but at levels higher than 250 mg.L^{-1}, Cl$^-$ causes odor and salty taste apart from aggravating heart problems and contributing to high blood pressure. The presence of Cl$^-$ in groundwater may possibly be due to the domestic wastages and/or leaching from upper soil layers in dry climates [9]. Chloride in surface and ground water generates from together natural and anthropogenic sources, for instance run-off comprising road de-icing salt in snowy place, the utilization of inorganic fertilizes, landfill leachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage, and seawater intrusion in coastal areas [13]. Chloride amounts in uncontaminated waters are frequently beneath 10 mg.L^{-1} and in some cases below 1 mg.L^{-1} [13]. Chloride in water might be substantially increased by remedy processes through which chlorine is employed.

4.7. Fluoride

Traces of fluoride tend to be present in numerous waters; nevertheless; greater concentrations are normally linked with underground sources. In sea water, an entire fluoride concentration of 1.3 mg.L^{-1} has long been noted [13]. In zones rich in fluoride-containing minerals, well waters may include up to about 10 mg of F$^-$ per liter. The top natural amount documented is 2800 mg.L^{-1} [13]. In groundwater, fluoride concentrations fluctuate with the kind of rock that the water passes through although never in most cases go beyond 10 mg.L^{-1} [13]. F$^-$ concentration in the groundwater of certain communities in China were higher than 8 mg.L^{-1}. In drinking water set from well water, concentrations up to 3.3 mg.L^{-1} in Canada [13]. In the USA, 0.2% of the citizenry is subjected to more than 2 mg.L^{-1} (EPA 1985). In certain African nations where the ground is abundant in fluoride-containing minerals, quantities in palatable water are comparatively excessive (e.g. 8 mg.L^{-1} in the United Republic of Tanzania) (EPA 1985). F$^-$ concentration value in the array of 0 to 0.1 mg.L^{-1} has been attained from the groundwater samples of the examined region and these valuations are within the permissible limits of WHO 2011 and Omani Standard No.8/2012 guideline. The source of F$^-$ in groundwater is generally assigned to leaching from fluoride rich rocks and simpler availability of rain water to weathered rock, long-term irrigation processes, semiarid to arid climate and long residence time of groundwater [9]. Sources of fluoride in bedrock aquifer systems consist of fluorite, apatite and fluorapatite. These kinds of minerals appear as evaporites or detrital grains in sedimentary rocks or as disseminated grains in unconsolidated deposits.

Groundwater fluoride illustrates variance according to the geological configurations [6]. Flouride doesn't clearly show its existence in all gathered samples from the examined region. Fluoride variation relies on a vast array of variables for example level of soluble and insoluble fluoride in source rocks, extent and contact of water with rocks, soil temperature, rainfall, oxidation-reduction procedure. Weathered item dissolves and leaches the fluorine minerals which lead to most to the surface and subsurface water figures during irrigation. The fluoride levels are identified to be fewer than the permissible limit of 1.5 $mg.L^{-1}$ [17] at all the governorate wells. Fluoride may be a fundamental component for human beings: the existence of modest proportions of fluoride in drinking water could protect against tooth decay. Fluoride at greater than 1.0 ppm the water needs to most likely be deflouridated for drinking appropriateness [6]. WHO recommends that the appropriate level of F^- in the drinking water should ranged from 0.6–0.8 ppm for annual average of maximum daily temperature of 26.3–32.6°C to 0.9–1.7 ppm for temperature of 10–12°C (WHO Guidelines 2006). However, the recommended level for tropical countries like Oman and Saudi Arabia, where the maximum temperature goes above 45◦C during summer season, should be in the range of 0.6–0.7 ppm [11]. Presence of large amount of F^- is associated with dental and skeletal fluorosis (>1.5 ppm) and inadequate amounts with the dental caries (<0.6 ppm) [11]. Furthermore, the concentration of F^- between 0.9–1.2 ppm may give mild dental fluorosis (WHO Guidelines 2006). It is due to the same fact of larger consumption of water in hot climate; the optimum level of fluoride in drinking water is suggested lower than temperate countries [11]. According to the data from the National Diet and Nutrition Survey for young people age 4–18 years in UK [18], the mean total daily bottled and tap water intake was 108 and 155 mL, respectively. The mean total daily intake of fluoride, i.e., the combination of tap and bottled water, was estimated to be 0.264 and 0.164 $mg.L^{-1}$, respectively.

4.8. Hardness

Carbonate hardness is mostly triggered by the carbonate and bicarbonate salts of calcium and magnesium. Non-carbonate hardness is an estimation of calcium and magnesium salts other than carbonate and bicarbonate salts (such as calcium sulfate, $CaSO_4$, or magnesium chloride, $MgCl_2$). Total hardness (that fluctuates in intensity according to alkalinity) is actually depicted as the total amount of carbonate hardness and non-carbonate hardness. In the majority of natural water the prevalent ions are those of bicarbonates affiliated predominantly with calcium to lesser degree with magnesium and still less with sodium and potassium [5]. Ingestion of saline water excessively is claimed to lead to hypertension and raises the threat of stroke, left ventricular hypertrophy, osteoporosis, renal stones and asthma [5]. The current investigation reveals that the total hardness reviewed in the water samples were determined in the range of 9-341.3 $mg.L^{-1}$ (Table. 3). The values of a few infrequent simples are found greater than the guideline as proposed by No.8/2012 (200 $mg.L^{-1}$). Nevertheless, the WHO guideline valuation (total hardness range: 80-120 $mg.L^{-1}$) implies that practically all the groundwater samples maxed the optimum limit for drinking water (Fig. 6). Calcium and magnesium are the main components accountable for water hardness results in dissolution of carbonate minerals such as calcite and dolomite. Hardness is an expression pertaining to the concentrations of specific metallic ions in water, primarily magnesium and calcium and is typically portrayed as an equivalent concentration of dissolved calcite ($CaCO_3$). In hard water, the metallic ions of concern may react with detergent to generate an insoluble deposit. These types of metallic ions could also react with adversely charged ions to provide solid precipitate if the water is hard. Total hardness is a measure of the capacity of water to the concentration of calcium and magnesium (usually expressed as the equivalent of $CaCO_3$ concentration). The values of this study show that TH is 80% based CH in all Buraimi wells (Table. 3). Abundance of carbonate hardness may be attributed due to dissolution of aragonite bearing minerals due to pedological differentiation in sedimentary cycle of depositional environment [6].

4.9. Alkalinity

The alkalinity of surface and ground waters is primarily due to the carbonate, bicarbonate, and hydroxide content and is often interpreted in terms of the concentrations of these constituents. The higher the alkalinity the greater the capacity of water to neutralize acids, conversely, the lower the alkalinity the less the neutralizing capacity. To detect the different types of alkalinity, the water is tested for phenolphthalein and total alkalinity.

All the sampling wells recorded normal values varying from 47.8 to 164.4 mg.L^{-1} (Fig. 7) and within the guideline as recorded by WHO 2011 for total alkalinity (200 mg.L^{-1}) (Table. 4).

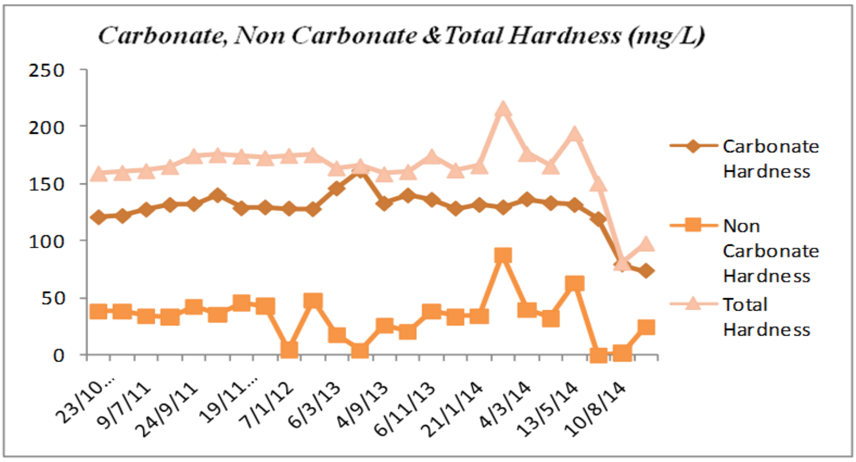


Figure 6: Hardness of one of the studied wells (UB1)

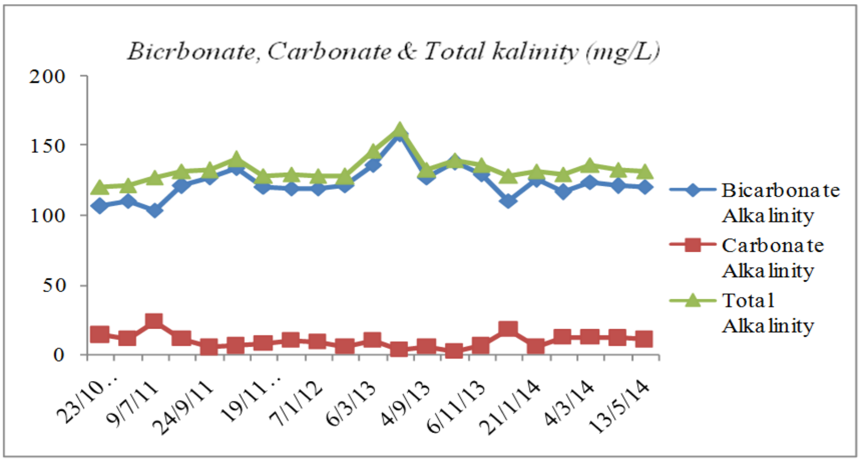


Figure 7: Alkalinity of one of the studied wells (UB1)

Total alkalinity in neutral water is attributed to bicarbonate [5]. Phenolphthalein alkalinity from 1 to 22.4 mg.L^{-1} is detected in all analyzed samples. Bicarbonate is an important anion in irrigation water as regards to calcium and a lesser degree to magnesium [6]. It brings about change in soluble sodium percentage in irrigation water; hence regulate the sodium hazard [6]. It varies from 48.1 to 183 mg.L^{-1}. All groundwater samples are within the prescribed limits of WHO, maximum permissible limit for HCO_3^- is found to be 300 mg.L^{-1} (WHO 2011). Being the abundant anion in the groundwater its dissolution in groundwater is mainly due to the dissolution of silicates and rock weathering [8]. Contribution is also made by atmospheric CO_2 and CO_2 released from the organic decomposition in the soil [19]. Carbonate varies from 1.2 to 26.9 mg.L^{-1}. Oxygen-deficient conditions are more likely to found at deep wells then in shallow wells because permeability of the carbonate bedrock decreases with depth, solution features and joints become smaller and less abundant [6].

Conclusion

In Buraimi region, Sultanate of Oman there is a semi public water supply system from Sohar city and the population in Buraimi district relies primarily on groundwater with regard to their demands. In the study area groundwater sucked from 21 bore wells had been analyzed regarding their chemical and physical attributes. The analytical outcomes of physical and chemical factors of groundwater ended up weighed against the standard guideline valuations advised by the World Health Organization (WHO, 2011) for drinking goal as well as the Omani standards (OS, 8/2012). Hydrochemically the ground water includes increased levels of E. C, Mg^{2+} in addition to hardness, reasonable values associated with TDS, pH, Ca^{2+}, Cl^-, HCO_3^-, CO_3^{2-} and alkalinity as well as reduced concentrations of F^-. Examination of the quality in groundwater out of 21 bore wells reveal that it belongs to hard to very hard category and groundwater from most of the bore wells from the study region is suitable for drinking purposes. The groundwater is laden with objectionable amount of cations and anions which may possibly have been derived through merged sources viz., mineralization, chemical weathering of rock, mine tailings, sewage contamination and intense agricultural activities. Chemical weathering of the rocks, open sanitation and agricultural return flow have led tremendously for the main components of the groundwater. This primary review calls for continuous monitoring of the quality of the groundwater in the region as further exploitation of groundwater may possibly boost the values of some of the parameters viz., TDS, Ca^{2+}, and F^- and deteriorate the water quality in near future which inevitably will confirm to be disastrous for the entire living beings in the region. Spatial distribution map of selected parameters prepared from the hydrochemical data in GIS environment is beneficial in determining the top groundwater quality zone within the study area.

List of abbreviation

EC	Electrical Conductivity	C.H.	Carbonate Hardness
T.D.S.	Total Dissolved Solids	N.C.H.	Non carbonate Hardness
Ca^{2+}	Calcium Ion	T.A.	Total Alkalinity
Mg^{2+}	Magnesium Ion	M.O.A	Methyl Orange Alkalinity
Cl^-	Chloride Ion	P.P.A.	Phenolphthalein Alkalinity
F^-	Fluoride Ion	C.A.	Carbonate Alkalinity
CO_3^{2-}	Carbonate Ion	B.C.A.	Bicarbonate alkalinity
HCO_3^-	Bicarbonate Ion	E.P.A	Environmental Protection
T.H.	Total Hardness	W.H.	World Health Organization

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