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Assessment of water quality in some wells in Albaha region and its surrounding area, Saudi Arabia

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Abstract This study aimed at assessment of some physical, chemical, and bacteriological parameters of some wells in Albaha region and its surrounding area, Saudi Arabia. Methodology: Physical parameters (total dissolved solids & turbidity) were analyzed by standard conductivity turbid meter. Chemical parameters (metal ions, sulfate, nitrate, nitrite and acidity) were measured by standard spectrophotometer and pH scale. EC blue 100® screening medium was employed to test for coliform bacteria in wells water. Results: Up to 73.7% of samples exceeded the permissible limits set by Saudi standards specified for total dissolved solids, turbidity, pH, Mn, SO_4 and NO_3.The average pH of targeted wells is 7.98 ± 0.37 which is within the permissible range specified by national and global standards. Detected levels (mg l^{-1}) of total dissolved solids, Fe, Mn, SO_4, NO_2, and NO_3 were 345.04, 0.62, 0.13, 5.74, 119.90, 52.74, and 0.157 mg l^{-1} respectively. Mn and NO_3 levels exceeded the permissible limits of Saudi and global health standards. About 36.8% of wells had a positive reaction for coliform presence by EC blue screening medium. In terms of spatial variations, no significant difference between individual sites was observed, however, sites as groups show remarkable variations in one group (SA) which had minor increases in NO_2levelscompared to other sites. Correlations between SO_4& total dissolved solids, Mn & NO_3, pH & total dissolved solids, SO_4& NO_3, and SO_4& Mn levels were found. Interpretation: Elevated levels of studied parameters in groundwater may be linked to agricultural and animal rearing practices. Precautions are highly recommended to avoid any public health hazards in future.

Keywords Albaha, chemical, Coliform bacteria Chemical, Spatial, Physical, Parameters, Water Quality

Introduction

Water is considered to be an important element to the life on the earth (Szewzyk *et al.*, 2000). Although, the importance of freshwater for the consumption and other different uses, many diseases can be transmitted by this important type of water (Hahn, 2006; Ozler & Aydin, 2008). In addition, freshwater represents the only 3% of the total water resources in the world, which is found in groundwater, lakes, and rivers(APHA, 2012). In rural area, groundwater is preferred for the purpose of drinking due to its quality and safety in comparison to surface water. However, increased human activates affected this groundwater quality and added lots of chemical, physical, and microbial pollutants(Okeola *et al.*, 2010; Patil *et al.*, 2012). In addition, the quality of groundwater can be influenced by other different factors, such as geology, weathering system, the amount of recharge water and the interaction between rock and water (Sethy *et al.*, 2016). In the ground aquifers, hand-dug wells (ancient wells) can be created.

These types of wells varied in both depth and the volume of water, and can be exposed to various chemical, physical and bacterial pollutants (Yakubu, 2013).

One of the most important key to assess the quality of groundwater is to measure its chemical composition. Increased concentrations of chemical elements in drinking water can result in critical health hazards(Mora *et al.*, 2017). For example, methemoglobinemia can be caused by consuming water containing high concentrations of nitrate(Fan & Steinberg, 1996). Also, a laxative gastrointestinal disturbance could be triggered by consuming water containing high levels of sulfate(WHO, 2017), while the risk of hypertension can be increased through the consumption of ground water with high concentrations of salts(Chao *et al.*, 2016).Generally, water-related diseases influenced millions of people every year especially children (Kisaka & Mato, 2018).

On the other hand, bacterial contamination of wateris the underlying cause of numerous water-borne diseases. Pathogenic bacteria should not be presented in drinking water. So, bacterial evaluation of groundwater intended to be consumed by human is an important health precaution(WHO, 1993). Coliform bacteria, including *Escherichia coli* (*E. coli*), have long been used as an indicators of water contamination. Coliform bacteria consist of total coliform bacteria and fecal coliform bacteria. Fecal coliform bacteria, such as *E. coli*are founded in the intestine of human and animals and their presence in water may indicate deposition of fecal materials. Consequently, drinking water should be tested for the presence or absence of coliform bacteria especially *E. coli*to guarantee its safety for human consumption (WHO, 2008).

The aims of this research are to (i) measure the concentrations of some physical, chemical parameters and also to screen for coliform bacteria and *E. coli*in some wells in Albaha region and surrounding area, (ii) compare these parameters with Saudi standards and WHO (World Health Organization) guidelines for drinking water quality, (iii) determine the effect of spatial variation on the concentrations of environmental parameters, and (iv) determine the relationships between environmental parameters.

Materials and Methods

The study sites

Nineteen wells were randomly selected from different zones in Albaha region and its surrounding area(Saudi Arabia) during 2017, (Figure 1) and (Table 1). Well sites were divided into 6 groups based on geographical locations (Figure 1) and (Table 2).Albaha region consists of different villages and almost half a million of population. In this region of Saudi Arabia, groundwater wells have long been used as the main source for drinking water and irrigation(Omer *et al.*, 2014).

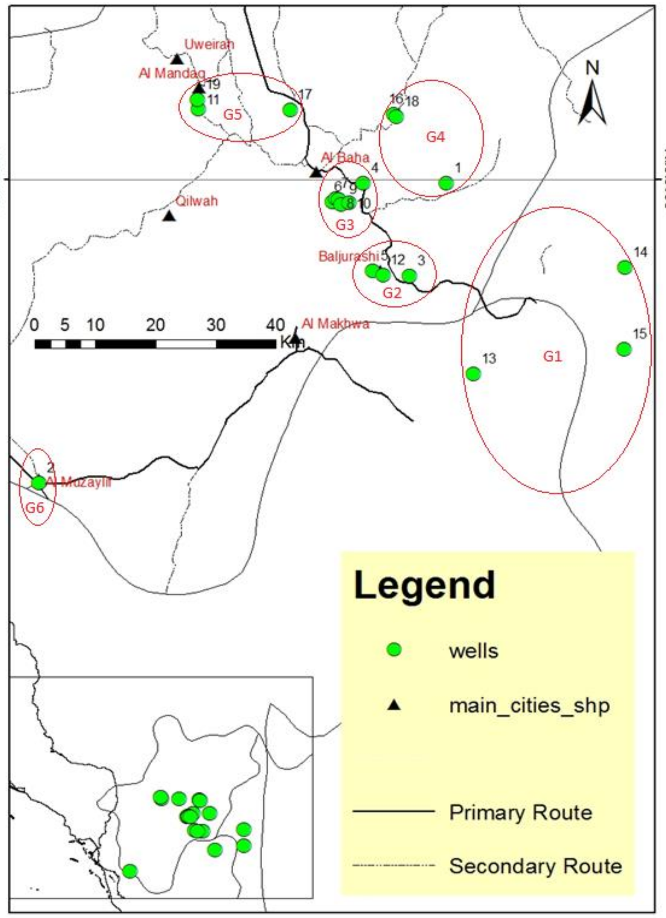

Figure 1. Geographical location of targeted wells (n=19)in six sites (as groups of wells, G1-G6) in Albaha region and its surrounding area (Saudi Arabia).

Table 1. Numbers, names and locations of targeted wells in Albaha region and its surrounding area (Saudi Arabia).

Well no.	Names of wells (location)	Coordination		Altitude (m)
		Latitude	Longitude	
1	Bani Kabir (South of Albaha)	19.994561	41.660098	1906
2	Almudailif (West of Albaha)	19.534829	41.050467	47
3	Alshatebah (Baljurashi)	19.851837	41.604840	2026
4	Alqohqoh(Marasiaah)	19.995739	41.535219	2133
5	Albahri, (Baljurashi)	19.859957	41.549216	2037
6	Adaros (Bani Dabian)	19.966935	41.490027	2313
7	Sobaiq (Bani Dabian)	19.971517	41.495268	2275
8	Asfal Alwadi (Bani Dabian)	19.970397	41.499260	2304

9	Sadd Alwadi (Bani Dabian)	19.963037	41.503160	2410
10	Alhanashah (Bani Dabian)	19.965565	41.514047	2393
11	Sadd Manshiah (Almandag)	20.108782	41.288857	2189
12	Alhoson (Baljurashi)	19.854214	41.564965	2027
13	Hawallah (South east of Albaha)	19.702417	41.700848	612
14	Shawas (South east of Albaha)	19.865282	41.927247	1624
15	Sadd Nabah (Albashayer)	19.739621	41.926028	1785
16	Alzayetonah Shoop Alhalah (Albaha)	20.101866	41.580797	1857
17	Alfaraah (Almosa)	20.107243	41.426129	2224
18	Alzayetonah, Shoop Alhallah (Albaha)	20.097328	41.585645	1866
19	Almaared (Almandag)	20.123787	41.288205	2151

Table 2. Sites as groups in Albaha region and its surrounding area, Saudi Arabia

Group number	wells no.	Group name	Symbol
1	13, 14 and 15	South east of Albaha	SA
2	3, 5 and 12	Baljurashi	BA
3	4, 6, 7, 8, 9 and 10	Bani Dabian	BD
4	1, 16 and 18	East of Albaha	EA
5	11, 17 and 19	Mandag	MA
6	2	Mudailif	MO

Sample collection

According to previously published methods(APHA, 1998; Behailu *et al*., 2018), water samples were collected from 19 wells during 2017 using sterile 100 mL bottles for bacterial examination,and polyethylene bottles for physical and chemical tests. Each sample was labeled and transported, and stored at 4 °C until analysis in the laboratory of Biological departments in the faculty of science and arts in Baljurashi. Environmental parameters were analyzed in the laboratory of public administration of water services in Albaha region.

Physical, chemical, and bacterial analyses

Physical parameters (Total dissolved solids and turbidity) were measured using conductivity meter and turbid meter (HQ14D, Hach, USA). Chemical parameters (Fe, Mn, SO_4, NO_3 and NO_2) were analyzed by spectrophotometer DR 2800 (Hach, USA), and pH meter PHS-25 (BANTE, China) was used to measure pH.

EC blue 100p (HyServe, Germany)screening medium was used to examine the presence and absence of coliform bacteria.100 mL of the sample was put into coliform water test sampling container followed by addition of EC blue 100p and shaking for 10 second beforeincubation at 37 ˚C for 48 hours. Color changes of the mixture to green or blue color indicates the presence of coliform bacteria, while no color change is indicative of coliform absence in the sample(JWWA, 2001; Kodaka *et al.*, 2008).

Statistical analysis

The statistical package of SPSS, version 20 (IBM) was used to analyze all physical, chemical and bacterial data. Kolmogorov-Smirnov tests was applied and some data that were not normally distributed were square root transformed. One-way ANOVA was applied to test the significant differences in all environmental parameters between individual sites and sites as groups. Spearman's rank correlations (*rs*) was used to examine the relationships between environmental parameters (Bolter *et al.*, 2002; Field, 2009).

Results and discussion

Water used for different purposes, such as drinking and irrigating should be tested for its quality. According to these purposes, one of the important key role to assess the quality of water is to select the required parameters to be tested(Al-Hasawi *et al.*, 2018). In this study, all parameters selection was based on their importance for determining quality of drinking water.

Comparison with Saudi standards and WHO guidelines of drinking water quality

Two physical (Total dissolved solids and turbidity) parameters, six chemical parameters (pH, Fe, Mn, SO_4, NO_3, NO_2), and also bacterial parameters are presented in Table 3 and Figures 2 to 18, respectively. All dissolved solids in water (manually mineral salts) are described as total dissolved solids (TDS) which are closely connected with conductivity (Iyasele *et al.*, 2015).TDS ranged from 0.02 to 741 mg l^{-1} in sites 1 and 18, respectively with mean and SD values of 345.04 ± 218.58mg l^{-1}(Table 3 and Figure 2A & B). Approximately, 26.3% of wells (5 out of 19) exceeded the maximum concentrations of TDS recommended by Saudi standards (max. 500 mg l^{-1}) but all TDS values did not exceed the maximum concentrations recommended by WHO guidelines (max. 1000mg l^{-1}) for drinking water quality. The slightly increases of TDS in sites 3, 3, 5, 16 and 18 may be as a results of both dissolving rocks in wells and application of fertilizers. Similar result documented by Rezaei & Hassani (2018) who assessed the quality of groundwater in the north of Isfahan, Iran and found that 14% of samples exceeded the maximum concentrations of TDS given by WHO.

The presence of turbidity in water with high values can affect other chemical and microbial parameters (WHO, 2004).Values of turbidity ranged from 0.14 to 3.51mg l^{-1} in sites 18 and 19, respectively (0.26 ± 0.43 mg l^{-1}) (Table 3 and Figure 2C&D). Only site 19 (5.3 % of all wells) exceeded the maximum concentrations of turbidity recommended by Saudi standards for drinking water quality (max. 1 NTU), while all concentrations of turbidity were below the maximum concentrations recommended by WHO guidelines (max. 5 NTU).This turbidity may be attributed to the presence of clay, silts, suspended solids, plankton and other microbes. Armah (2014) found turbidity is one of the most significant factors predict total coliform bacteria in mining environment in Ghana.

ThepH values ranged from 7.34 to 8.67 SU in sites 14 and 11 (7.98 ± 0.37 SU) (Table 3 and figure 2E &F). Sites 11 and 8 (10.5% of the total wells) exceeded slightly the maximum concentrations of pH recommended by Saudi standards and WHO guidelines (max. 8.5 SU) for drinking water quality, while the other values of the other sites were within the recommended range (6.5 – 8.5 SU). The result of all values of pH in this study including sites 11 and 19 reflect that groundwater was slightly basic which is the same result obtained by Al-Hasawi *et al.*(2018) in the study of groundwater in Rabigh governorate, Saudi Arabia.

Fe is one of the most abundant element on the earth crust. The more ion in water the more inconvenient for human consumption since it produces undesirable color and taste(Zogo *et al.*, 2010). Values of ferrous (Fe) ranged from 0.01 to 0.3 mg l^{-1} in sites 18 and 5 (0.13 ±0.10mg l^{-1}) (Table 3 and figure 3A &B). No values of Fe exceeded the maximum concentrations recommended by Saudi standards and WHO guidelines for drinking water quality (max. 0.3 mg l^{-1}). This result is in consistent with the results obtained by Kisaka & Mato (2018) who found the Fe within the permissible concentration in groundwater in Tanzania.

Manganese (Mn) can be found naturally in groundwater resulting from soluble of bedrock and also it can be leached into groundwater from human practices (Ljung & Vahter, 2007). Mn values ranged from 0 to 103 mg l^{-1} in sites 8 and 1 (5.74 ± 23.56 mg l^{-1}) (Table 3 and figure3C & D). Approximately, 31.6% of the total wells (sites; 1, 2, 7, 16, 17 and 19) slightly exceeded the maximum concentrations of Mn recommended by Saudi standards for drinking water quality. Similarly, all sites mentioned above except site 16 (26.3% of total wells) slightly exceeded the maximum concentrations of WHO guidelines. The large value of Mn was recorded in site 1(103 mg l^{-1}) in Bani Kabir (Table 1& Figure 1).Increased Mn levels in groundwater (above 0.4 mg l^{-1}) can be risky to health (WHO, 2017). High levels have been documented in studies elsewhere and attributed to both intensive agriculture practices and Mn ions naturally found in groundwater(Phan *et al.*, 2013; Van *et al.*, 2016).

Sulfate (SO_4) can be found in groundwater from both natural and anthropogenic sources (in the form of fertilizers). Water–related diseases, such as diarrhea, especially to young children, can be caused by high concentrations of SO_4 in drinking water (Kisaka & Mato, 2018; Miao *et al.*, 2012). Values of sulfate (SO_4) ranged from 1.12 to 629 mg l^{-1} in sites 1 and 5 (119.90 ± 176.46mg l^{-1}) (Table 3 and figure 3E& F). Three out of 19 wells (15.8%) (sites; 5, 6 and 7) exceeded the maximum concentrations of SO_4 recommended by Saudi standards and WHO guidelines for drinking water quality. The study of the source of SO_4 in groundwater in the Jinghuiqu district (China) found increases of SO_4 during the period of time from 1990 to 2009 mainly due to dissolution of minerals(Liu *et al.*,2012).

Nitrate (NO_3) can easily reaches the groundwater through agricultural activities, sewage contamination, and from the atmosphere (Ritzi *et al.*, 1993). Nitrate (NO_3) values ranged from 0.2 to 709.8 mg l^{-1} in sites 7 and 19 (52.74 ± 168.20mg l^{-1}) (Table 3 and figure 4A&B). Two sites (10.5% of total wells) showed elevated values of NO_3exceedingthe maximum concentrations recommended by Saudi standards and WHO guidelines for drinking water quality. The highest values were in site 19 (709.8 mg l^{-1}) followed by site 1 (240 mg l^{-1}). The increased concentrations of NO_3 in sites 1 and 19 may had resulted from agriculture practices through applying animal manure and inorganic nitrogenous fertilizer discharging into water wells. Recent study of the source of NO_3 in groundwater conduct by Bourke and associates(2019) concluded that increased NO_3 most likely attributed to mixing or denitrification and also agriculture activities.

Nitrite (NO_2) values ranged from 0.001 to 0.044 mg l^{-1} in sites 4 and 13 (0.157 ± 0.011mg l^{-1}) (Table 3 and figure4C&D). No wells exceeded the maximum concentrations of NO_2 values recommended by Saudi standards and WHO guidelines for drinking water quality. The NO_2 can be naturally found in groundwater as a result of nitrogen cycle (Nas & Berktay, 2005).

Results of EC blue analysis are presented in Table 3and Figure 5. Approximately, 36.8% of wells (sites; 2, 3, 4, 8, 11, 13 and 16) are contaminated with coliform bacteria. These pathogenic bacteria should not be founded in water used for drinking purpose and their viable count should be 0 per 100 mL (RCER, 2015; SASO, 2000; WHO, 2004, 2017).

The presence of coliform bacteria and *E. coli* in the wells mentioned above may resulted from deposition of animal manure, sheep and goats faces around the opened wells especially after rainfall events. Sakami et al.(2003) stated that groundwater receives pathogens from animal manure after rainfall events.

A recent study revealed that all water sources including wells used for drinking purpose except tanks, in Baljurashi city, Albaha region were contaminated with coliform bacteria and *E coli*(Omer *et al.*, 2014). It should be noted that positive results of coliform bacteria assay do not necessarily reflect a fecal contamination of water. All coliform genera, except *E. coli*, have been isolated from natural samples of non-fecal origin and all genera show a positive reaction in this assay (Doyle & Erickson, 2006).

Table 3. Details of some physical, chemical and bacterial parameters of targeted wells in Albaha region and its surrounding area.

Well no.	Parameters								Coliform bacteria
	pH	TDS (mg l^{-1})	Turbidity (NTU)	Fe (mg l^{-1})	Mn (mg l^{-1})	SO_4 (mg l^{-1})	NO_3 (mg l^{-1})	NO_2 (mg l^{-1})	
1	8.37	0.02	0.330	0.03	103	1.12	240	0.020	–
2	7.86	573	0.750	0.02	0.6	81	1.1	0.040	+
3	7.91	638	0.500	0.23	0.1	75	3.1	0.020	+
4	8.12	351	0.160	0.15	0.3	64	0.5	0.001	+
5	8.09	629	0.260	0.26	0.01	629	2.7	0.020	–
6	7.96	399	0.770	0.14	0.1	399	1.5	0.012	–
7	7.69	469	0.450	0.03	0.7	469	0.2	0.018	–
8	8.63	159.4	0.380	0.22	0	123	0.3	0.014	+
9	7.88	158.5	0.570	0.1	0.1	16	0.7	0.010	–
10	8.37	99.7	0.300	0.02	0.3	9	3.3	0.020	–
11	8.67	80.7	0.220	0.23	0.2	21	23.9	0.004	+
12	8.36	104	0.240	0.16	1	7	3.3	0.010	–
13	7.35	377	0.520	0.05	0.2	32	2.5	0.044	+
14	7.34	341	0.490	0.3	0.1	34	0.4	0.022	–
15	7.61	466	0.890	0.1	0.1	75	1.3	0.010	–
16	7.82	501	0.530	0.3	0.5	38	1.9	0.005	+
17	7.99	347	0.780	0.02	0.7	59	3.8	0.002	–
18	7.74	741	0.140	0.01	0.1	113	1.7	0.017	–
19	7.93	121.4	3.510	0.05	0.9	33	709.8	0.009	–
Mean ± SD	**7.98 ± 0.37**	**345.04 ± 218.58**	**0.62 ± 0.43**	**0.13 ± 0.10**	**5.74 ± 23.56**	**119.90 ± 176.46**	**52.74 ± 168.20**	**0.157 ± 0.011**	**NA**
Range	**7.34 – 8.67**	**0.02 - 741**	**0.14 - 3.51**	**0.01 - 0.3**	**0 - 103**	**1.12 - 629**	**0.2 - 709.8**	**0.001 - 0.044**	**NA**
KSA PL	**6.5 - 8.5**	**500**	**1**	**0.3**	**0.4**	**250**	**50**	**0.2**	**–**
WHO PL	**6.5 - 8.5**	**500 - 1000**	**5**	**0.3**	**0.1 - 0.5**	**250**	**50**	**3**	**–**

WHO: world health organization, PL: permissible limits, SD: standard deviation, NA: not applicable.

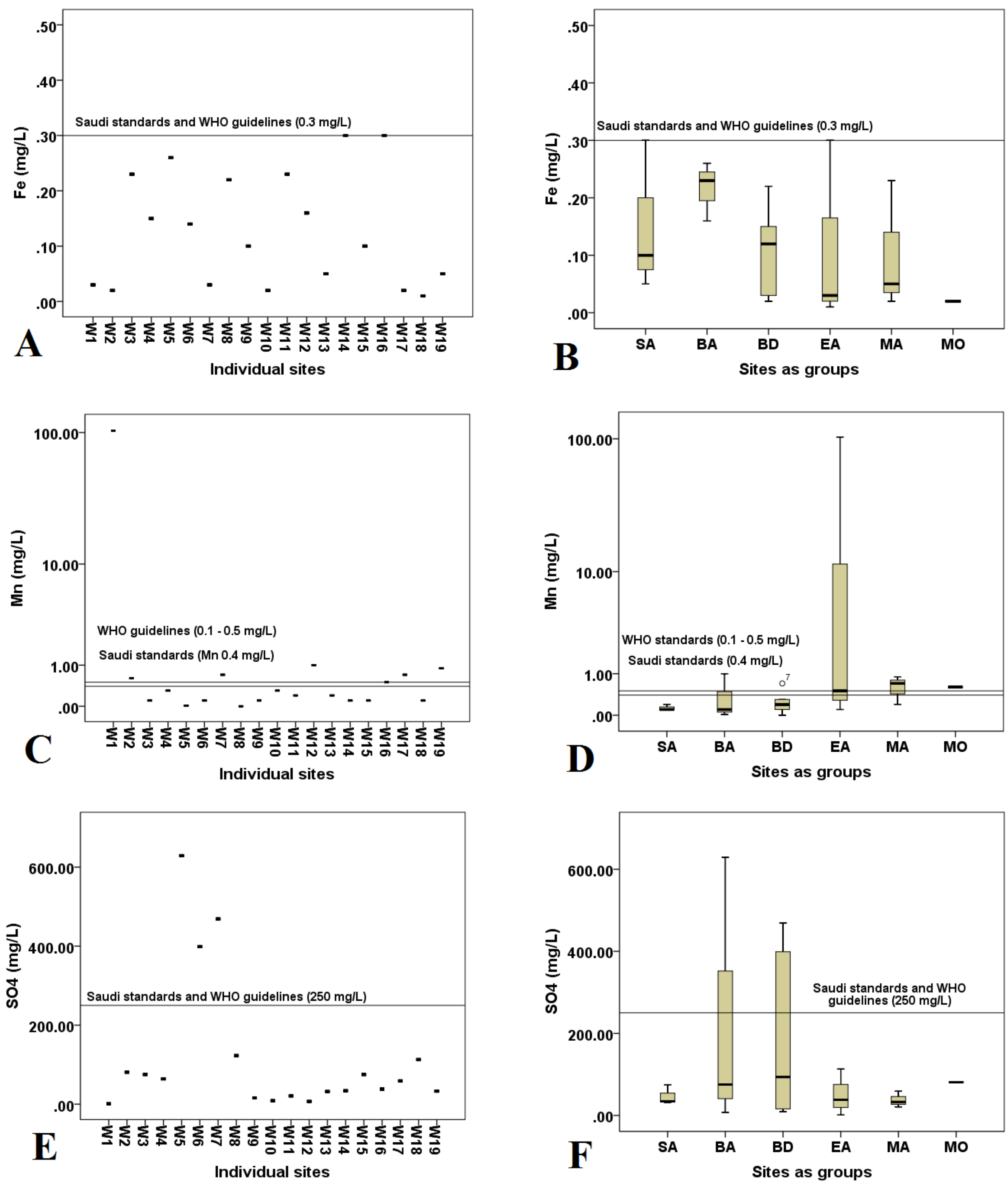

Figure 2. Variation of TDS (A & B), turbidity (C & D), and pH (E & F) between individual sites and sites as groups in some wells in Albaha region and its surrounding area, Saudi Arabia during 2017.

Figure 3. Variation of Fe (A & B), Mn (C & D), and SO_4 (E & F) (mg l^{-1}) between individual sites and sites as groups in some wells in Albaha region and its surrounding area, Saudi Arabia during 2017.

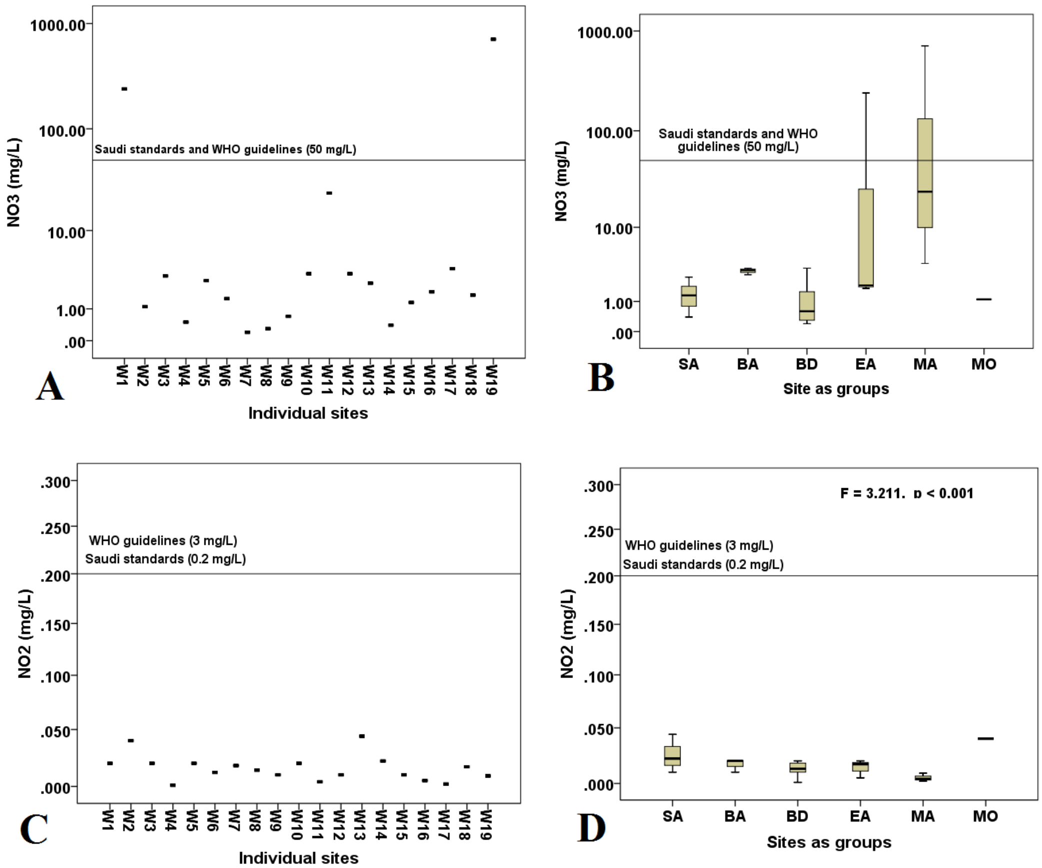

Figure 4. Variation of NO_3 (A & B) and NO_2 (C & D) (mg l^{-1}) between individual sites and sites as groups in some wells in Albaha region and its surrounding area, Saudi Arabia during 2017.

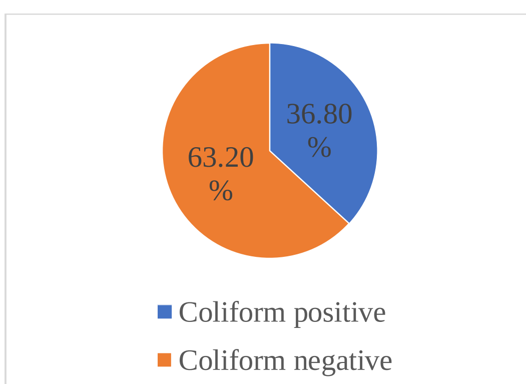

Figure 5. Percentage of coliform presencein individual sites in some wells in Albaha region and its surrounding area, Saudi Arabia during 2017.

Effects of spatial factors on the variation of environmental parameters

It is important to study of spatial effects on variations of physical, chemical, and microbial parameters. These parameters can be driven by geology, climate conditions and human activities(Ali & Ali, 2018).Effects of spatial factors on the variation of physical, chemical and bacterial parameters are presented in Table 2 and figures 1 & 17. One –Way ANOVA analysis shows no significant effects of individual sites on the variation of all environmental parameters investigated. However, sites as groups revealed significant effect on the variation of only nitrite (NO_2) (F = 3.21, $p < 0.001$) in group 1 (SA) (see figures 1 & 17 and Table 2). Additionally, all values of NO_2at all sites do not exceed the maximum concentrations recommended by WHO guideline and Saudi standards for drinking water quality. The slight increases ofNO_2 concentrations in group 1(SA)compared with other groups in this research may be due tonaturaleffect as a part of nitrogen cycle(Bourke *et al.*, 2019; Nas & Berktay, 2005).

Significant relationships between environmental parameters

Previous studies of groundwater contamination had emphasized on the interplay between different environmental parameters by employing correlation coefficient statistics. This type of statistical analysis helps researchers to find out how environmental parameters effect water quality and accordingly how to manage strategies of water(Otu *et al.*, 2014).

Significant sportsman's correlations coefficient analysis between all environmental parameters are presented in table 4 and figures 19 to 23.pH was negatively correlated with TDS (r_s = - 0.574, p < 0.05) (Figure 19). This result reflects that the more basic water the less TDS concentration and vice versa. This result differs with the result obtained by Mahato et al.(2018) who found a low positive correlation between pH and TDS in groundwater in eastern Terai region of Nepal.

Results have also showed various significant correlations between $SO_4$and different environmental parameters. These results suggest that TDS, Mn and NO_3 influenced the SO_4. The $SO_4$was strongly positively correlated with TDS (r_s = 0.771, p < 0.001) (Figure 20) and this observation is in good agreement with results of Salem & Alshergawi (2013) who studied51 wells used for drinking water in

Alshati district of Libya. Also, SO_4 was negatively correlated NO_3 (r_s = - 0.535, p < 0.05) (Figure 23).Similar result obtained by Kong*et al.* (2013) but in different environment (atmospheric particles). In contrast, Kim *et al.*(2005) observed a positive correlation between SO_4 and NO_3 in groundwater in Namwon, Korea. The SO_4 was also negatively correlated with Mn (r_s = - 0.500, p <0.05) (Figure 21). Similar weak negative correlation in groundwater was found by Shroff *et al.*(2015) in Valsad district of south Gujarat, India. Moreover, Mn was positively correlated with NO_3 (r_s = 0.457, p <0.05) (Figure 22). Other studies, for example, Bishnol & Malik (2008) and Salem & Alshergawi (2013)found no relationships between Mn and all the investigated environmental parameters including NO_3 in groundwater.

Overall, physical chemical and bacterial parameters were studied in Albaha region and its surrounding area, Saudi Arabia. More than two thirds of wells are unsuitable for drinking and irrigation purposes due to inconsistencies with Saudi and WHO standards in terms of physical, chemical, and bacteriological parameters. Increases in TDS, turbidity, pH, SO_4, NO_3 and Mn, were found along with coliform bacteria. No statistically significant variations of environmental parameters were observed between individual well sites. Significant correlations were found between TDS and sulfate levels, Mn and nitrate, pH and TDS, and sulfate and nitrate. Urgent treatment for wells in Albaha region is strongly advised. Further investigations of groundwater quality in terms of temperature, heavy metals contents are highly recommended.

Table 4. Relationship between environmental parameters in some wells in Albaha region and its surrounding area

Parameter	pH	TDS (mg l^{-1})	Turbidity (NTU)	Fe (mg l^{-1})	Mn (mg l^{-1})	SO_4 (mg l^{-1})	NO_3 (mg l^{-1})	NO_2 (mg l^{-1})
pH	–	rs = -.574*, $p < 0.05$	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
TDS (mg l^{-1})	rs = -.574*, $p < 0.05$	–	N.S.	N.S.	N.S.	rs = .771**, $p < 0.001$	N.S.	N.S.
Turbidity (NTU)	N.S.	N.S.	–	N.S.	N.S.	N.S.	N.S.	N.S.
Fe (mg l^{-1})	N.S.	N.S.	N.S.	–	N.S.	N.S.	N.S.	N.S.
Mn (mg l^{-1})	N.S.	N.S.	N.S.	N.S.	–	rs = -.500*, $p < 0.05$	rs = .457*, $p < 0.05$	N.S.
SO_4 (mg l^{-1})	N.S.	rs = .771**, $p < 0.001$	N.S.	N.S.	rs = -.500*, $p < 0.05$	–	rs = -.535*, $p <0.05$	N.S.
NO_3 (mg l^{-1})	N.S.	N.S.	N.S.	N.S.	rs = .457*, $p < 0.05$	rs = -.535*, $p <0.05$	–	N.S.
NO_2 (mg l^{-1})	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	–

Key symbols: SU: standard unit, N.S.: not significant, *rs*: Superman's rank correlation.

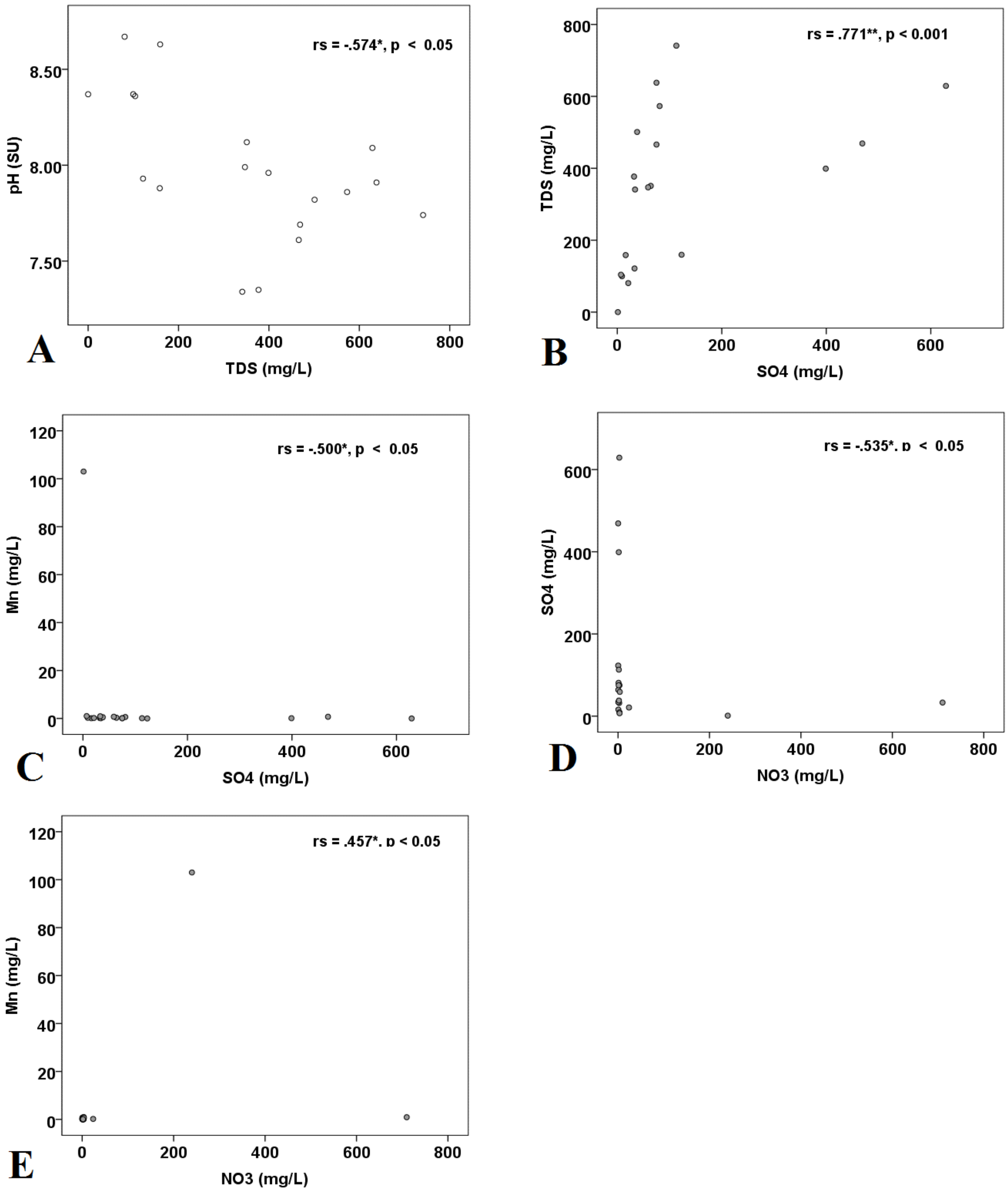

Figure 6. Relationship between pH (SU) – TDS (A), TDS– SO_4 (B), Mn– SO_4 (C), SO_4– NO_3 (D) and Mn– NO_3 (E) in some wells in Albaha region and its surrounding area, Saudi Arabia during 2017.

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