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Original article

Investigation of some physical, chemical, and bacteriological parameters of water quality in some dams in Albaha region, Saudi Arabia

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A R T I C L E I N F O

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A B S T R A C T

This study was conducted to evaluate the quality of water in selected dams in Albaha region, Kingdom of Saudi Arabia. Water samples from eight dams were subjected to physical, chemical, and bacteriological assessment using standardized procedures of conductivity, total dissolved solids, ions, acidity & alkalinity, and EC blue 100® coliform detection. About three fourth (75%) of dams' water samples exceeded the permissible levels of pH, total dissolved solids, turbidity, Mn and NO_3 set by Saudi standards. Average levels of total dissolved solids, Fe, Mn, SO_4, NO_3, and NO_2 were 3065.00, 0.10, 0.89, 68.25, 17.91 and 0.016 mg/L, respectively. However, the average pH of water samples was 7.95 ± 0.66 which still within the accepted range set by national and global standards. Moreover, total dissolved solids also exceeded regular standards of Food and Agriculture Organization for irrigation water quality. Coliform bacteria were detected in 37.5% of dams without any significant spatial differences between dams and sites as groups. Correlations were found between pH & NO_3, SO_4 & NO_3, coliform bacteria & turbidity, coliform bacteria & NO_2 levels. Increased concentrations of assessed parameters in dams may be attributed to agricultural activities as well as animal and human wastes deposited into dams via rainfalls and flash floods. Proper treatment of dams needs to be taken into account before consumption and irrigation.

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1. Introduction

Dams are considered one of the most important sources of water in Saudi Arabia (Al-Ghamdi et al., 2014). Currently, the number of dams in Saudi Arabia is estimated to reach 237 dams collecting water from rainfalls for various purposes (Zaharani et al., 2011). Recent work on seventeen dams in Albaha region ordered the purposes of these dams in such area to recharge nearby wells, protection against floods, and irrigation representing 76.5%, 17.6%, 59%, respectively (El-Hazek, 2013). However, the quality of water stored in such constructed reservoirs is subjected to various factors such as poisonous substances and microbial contaminants from rainfalls, air, dead plants and animals, soil, and domestic wastes (Arora and Arora, 2020). Additionally, increased salinity is a usual outcome of water evaporation (Kalitsi, 2008).

Several natural and anthropogenic factors are known to negatively affect water quality. The natural factors affecting water quality include geological & hydrological processes and climatic changes, which may be gradual or rapid. The natural factors range from bedrock weathering & atmospheric deposition of dust and pollutants to large scale disasters such as algal blooms, floods, droughts, and earthquakes (Khatri and Tyagi, 2015). On the other hand, anthropogenic factors are the most profound causes of deteriorating water quality. Indeed, agricultural & farming activities, industrial & municipal wastes, constructions and mining operations are the main cause of water pollution with pesticides, xenobiotic organic compounds, heavy metals, acids, and numerous oxides (Bojarczuk et al., 2018).

Chemical and physical parameters affecting water quality require continuous monitoring to avoid health hazards before dam water is used for drinking, irrigation, and industrial purposes (Chaudhari et al., 2016; Gulumbe et al., 2016; Mora et al., 2017; Mulamattathil et al., 2015). Increased concentrations of certain metals and oxides may cause many diseases, mostly in young children, such as methemoglobinemia, manifested by laxative gastrointestinal disturbance and hypertension (Chao et al., 2016; Fan and Steinberg, 1996; Kisaka, 2018; WHO, 2017).

Waterborne diseases are considered to be the main concern of public health authorities in developing and developed countries.

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The detection of indicator bacteria in water, such as coliform and fecal coliform suggests the presence of fecal contamination, and thus water should be assessed to guarantee its safety for human consumption (AlOtaibi, 2009; WHO, 2011).

The current study aimed at determining water quality of targeted dams in Albaha region, with specific objectives of: (i) examining of some physical, chemical, and bacteriological properties of water, (ii) comparison of these parameters to Saudi and WHO drinking water quality standards, and also to FAO (Food and Agriculture Organization) for irrigation water quality (iii) addressing the effects of spatial distribution on differences of addressed physico-chemical parameters of water and the correlations between all the parameters.

2. Materials and methods

2.1. Study site

A total of eight dams from different locales (Fig. 1 & Table 1) were incorporated in the current study conducted in 2017 in Albaha region. Based on geographical locations, dams were divided into four groups (Fig. 1 & Table 2). Albaha region is located in the western south of Saudi Arabia containing six governorates and almost half a million capita of the population (El-Hazek, 2013).

2.2. Sample collection

Water samples from targeted dams were collected in sterile bottles for bacteriological analysis, while samples for physico-chemical analysis were collected in polyethylene containers (Behailu et al., 2017). After collection, samples were labeled and transported to the laboratory of the Biological Sciences department, Faculty of Sciences and Arts, Albaha University. Samples for Physico-chemical evaluation were transported to the laboratory of the Public Administration of Water Services in Albaha region.

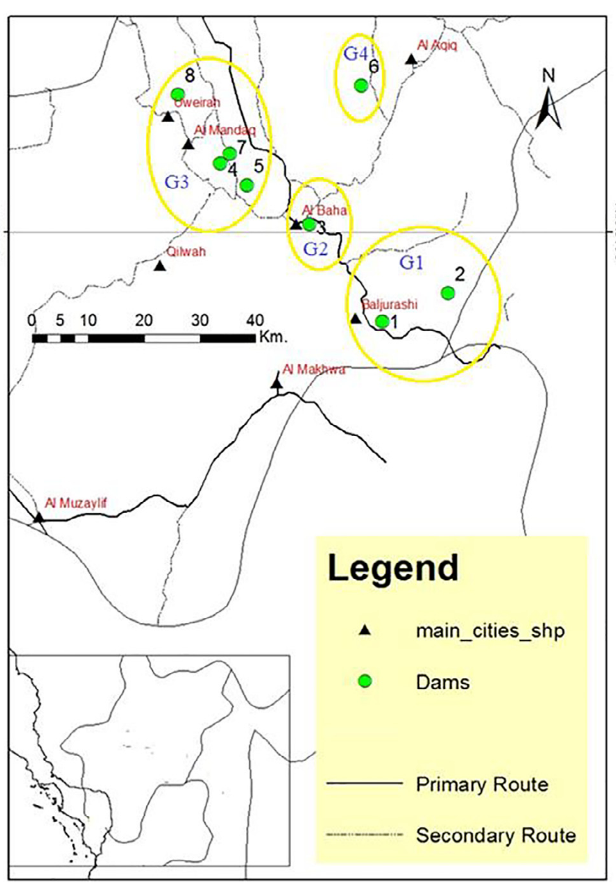

Fig. 1. Geographical location of targeted dams.

2.3. Analysis of physical parameters

The physical parameters were assessed according to previously published methods (Albaggar, 2020). Total dissolved solids (TDS), and turbidity, and pH were assessed in water samples by a standard turbidimeter (HQ14D, Hach, USA) and a standard pH scale (PHS-25, Bante, China). Recorded measures were compared to standards of the World Health Organization (WHO), Food and Agriculture Organization (FAO), and Saudi standards (FAO, 1992; SASO, 2002; WHO, 2017).

2.4. Analysis of chemical parameters

Spectrophotometer DR 2800 (Hach, USA) was employed for assessment of Fe, Mn, SO_4, NO_3 and NO_2. All values were evaluated against Saudi standards (SASO, 2002), WHO standards for drinking water quality (WHO, 2017), and FAO standards for irrigation water (FAO, 1992).

2.5. Bacteriological evaluation

Detection of coliform bacteria was performed by EC blue 100p screening medium according to manufacturer's instructions (HyServe, Germany). Briefly, 100 mL of water sample along with the EC blue 100p were added to the test container and mixed thoroughly for 10 s and incubated aerobically at 37 °C for 48 h. Change in color to green or blue after the incubation period was considered an indication of coliform presence (JWWA, 2001; Kodaka et al., 2008).

2.6. Statistical analysis

Data were digitally stored and analyzed by version 20 of SPSS (IBM Chicago USA). Data with non-normal distribution were analyzed by Kolmogorov-Smirnov tests and square root transformed. The difference between the physico-chemical parameters in different sites was tested by One-way ANOVA. The relationships between these parameters were assessed by Spearman's rank correlation test (Bölter et al., 2002; Field, 2009)

3. Results

Physico-chemical and bacterial parameters of dams' water quality in Albaha region were evaluated and compared to Saudi and WHO drinking water quality standards, and also to irrigation water standards set by FAO. Results of physical, chemical and bacterial parameters are presented in Table 3 and Figs. 2 & 3.

3.1. Physical parameters of dams' water

In the present study, TDS levels (3065 ± 7335.23 mg/L) ranged from 177 to 21207 mg/L (Table 3 and Fig. 2). Approximately, 37.5% of dams exceeded the maximum concentrations of TDS specified by Saudi standards (max. 500 mg/L), while 25% exceeded the maximum concentrations set by WHO (max. 1000 mg/L) for drinking water quality. Similarly, 25% of dams exceeded the accepted limits of turbidity defined by Saudi standards for drinking water quality (max. 1 NTU), while only one site slightly exceeded the

Table 1
Names and locations of targeted dams in Albaha region (Saudi Arabia).

Dam no.	Names of dams (location)	coordination		Altitude (m)
		Latitude	Longitude	
1	Altalqiyah (Baljurashi)	19.854676	41.603843	2024
2	Alganabaeen (West of Albaha)	19.900708	41.710589	1801
3	Almalad (Baljurashi)	20.012891	41.486564	2105
4	Ajlan (Albaha)	20.110395	41.342832	1990
5	Alwadi Aldahyan, (Almandaq)	20.075923	41.385854	2077
6	Alaqiq (East of Albaha)	20.236442	41.570698	1636
7	Wadi Alssadr (Almandaq)	20.126844	41.358233	1945
8	Medhas (Almandaq)	20.222282	41.274311	1777

Table 2
Dams as groups in Albaha region, Saudi Arabia.

Group number	Dams no.	Group name	Symbol
1	1 and 2	South east of Albaha	SA
2	3	Albaha city	AB
3	4, 5, 7 and 8	North of Albaha	NB
4	6	East of Albaha	EA

accepted range set by WHO. The pH values ranged from 6.74 to 8.95 SU in sites 8 and 3 (7.95 ± 0.66 SU). Only site 3 (12.5% of the total dams) exceeded the maximum limits for drinking water specified by Saudi & WHO standards and FAO guidelines (se. > 8 SU) for irrigation water.

3.2. Chemical parameters of dams' water

Average values of iron (Fe), sulfate (SO_4), and Nitrite (NO_2) are all within the standard ranges (Fig. 3 & Table 4). Nitrate (NO_3) values ranged from 0.2 to 129.3 mg/L (17.91 ± 45.05 mg/L). Only site 8 (12.5% of total dams) showed a high value of NO_3 exceeding the maximum level set by Saudi and WHO standards for drinking water quality, and also exceeded severe concentration specified by FAO (se. > 30 mg/L) for irrigation water quality. On the other hand, Mn values ranged from 0.02 to 2.4 mg/L (0.89 ± 0.89 mg/L) (Table 3 and Fig. 3). Approximately, 50% of the targeted (sites; 2, 3, 4 and 8) exceeded the maximum concentrations of Mn specified

Table 3
Details of some physical, chemical and bacterial parameters of targeted dams in Albaha region.

Dam no.	Parameters								Coliform bacteria
	pH	TDS (mg/L)	Turbidity (NTU)	Fe (mg/L)	Mn (mg/L)	SO_4 (mg/L)	NO_3 (mg/L)	NO_2 (mg/L)	
1	8.50	402	0.120	0.20	0.30	88	0.20	0.016	–
2	7.69	346	0.340	0.06	1.90	70	1.90	0.014	–
3	8.95	360	0.710	0.20	0.80	12	0.80	0.001	+
4	7.62	517	0.400	0.02	2.40	95	5.80	0.025	–
5	8.28	435	4.040	0.01	0.30	102	3.80	0.013	+
6	7.98	177	0.400	0.02	0.02	22	0.20	0.054	–
7	7.88	21,207	0.290	0.18	0.10	54	1.30	0.003	–
8	6.74	1076	5.100	0.10	1.30	103	129.30	0.001	+
Mean ± SD	7.95 ± 0.66	3065.00 ± 7335.23	1.43 ± 1.97	0.10 ± 0.08	0.89 ± 0.89	68.25 ± 35.78	17.91 ± 45.05	0.016 ± 0.018	NA
Range	6.74 – 8.95	177–21207	0.120–5.100	0.01–0.2	0.02–2.4	12–103	0.2–129.3	0.001–0.054	NA
KSA PL	6.5–8.5	500	1	0.3	0.4	250	50	0.2	0 per 100 mL
WHO PL	6.5–8.5	500–1000	5	0.3	0.1–0.5	250	50	3	0 per 100 mL
FAO SE.	> 8	>2000	–	>1.5	>1.5	–	>30	–	–

WHO: world health organization, PL: permissible limits, SD: standard deviation, NA: not applicable, FAO: Food and Agriculture Organization, SE: severe concentration.

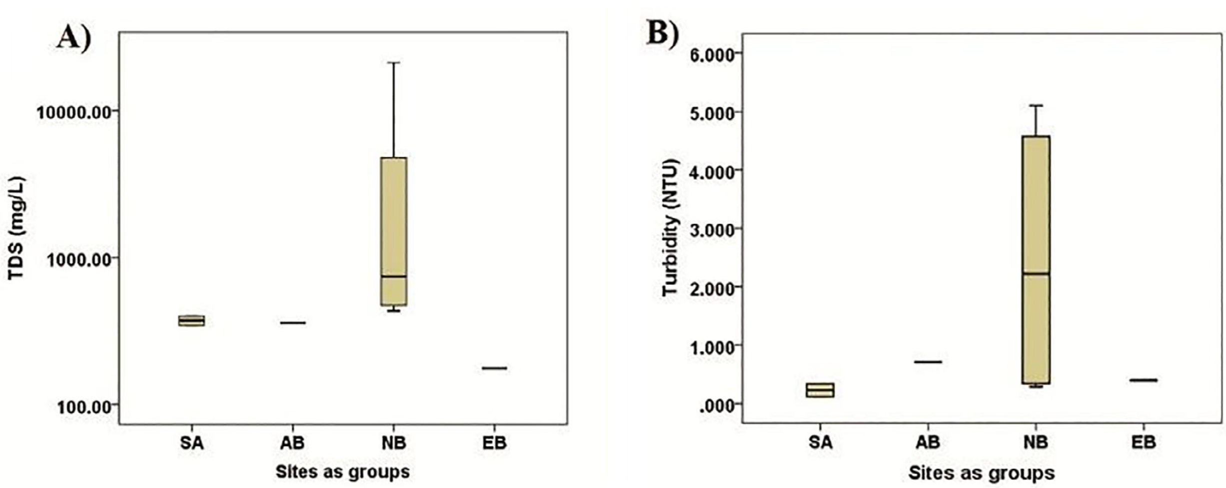

Fig. 2. Variation of physical parameters of dams' water between sites as groups.

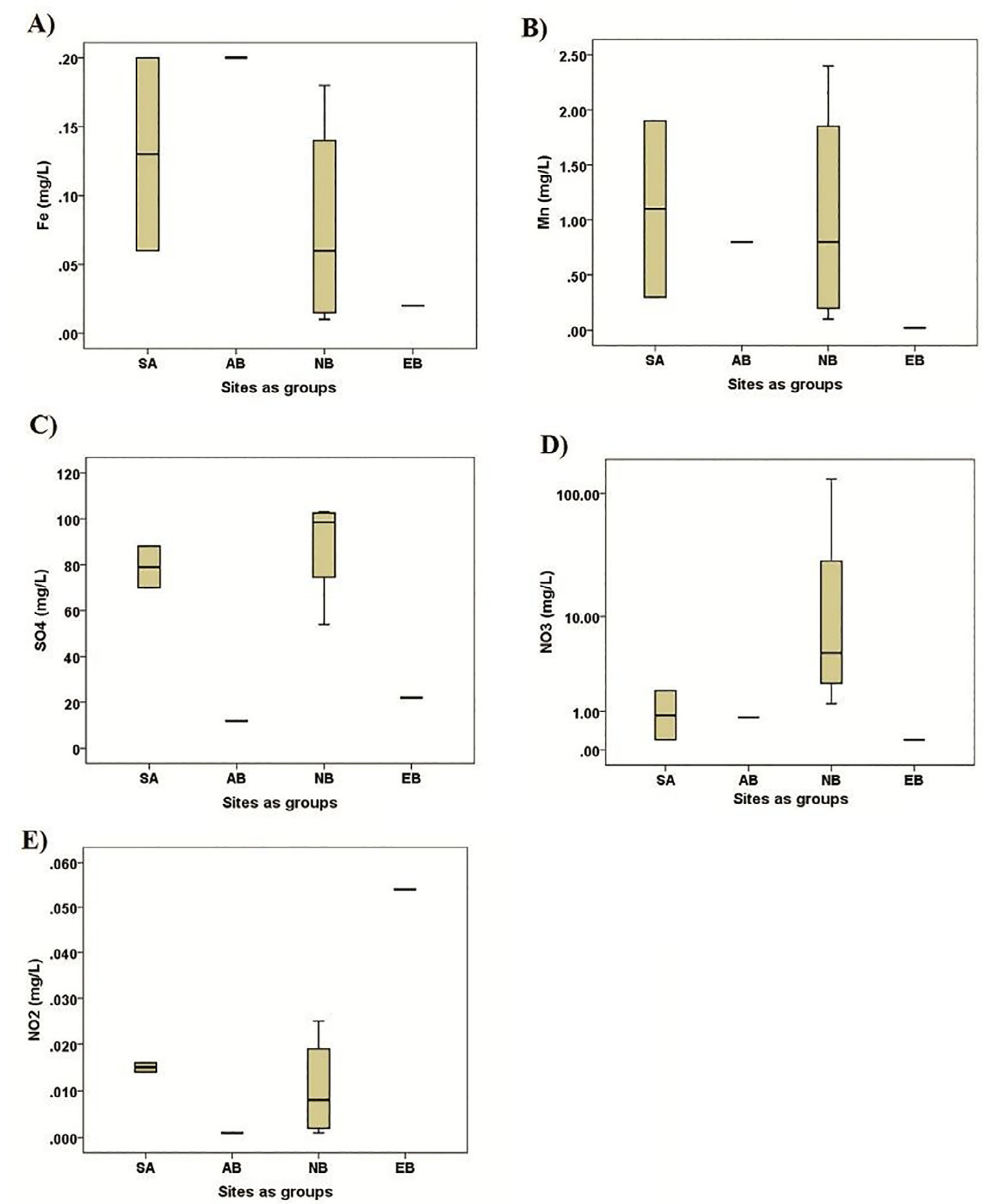

Fig. 3. Variation chemical parameters of dams' water between sites as groups.

Table 4
Relationship between physico-chemical parameters of water in some dams in Albaha region.

Parameter	pH	TDS (mg/L)	Turbidity (NTU)	Fe (mg/L)	Mn (mg/L)	SO_4 (mg/L)	NO_3 (mg/L)	NO_2 (mg/L)	The presence of coliform
pH	–	N.S.	N.S.	N.S.	N.S.	N.S.	r_s = -0.743*, p < 0.05	N.S.	N.S.
TDS (mg/L)	N.S.	–	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Turbidity (NTU)	N.S.	N.S.	–	N.S.	N.S.	N.S.	N.S.	N.S.	r_s = 0.850**, p < 0.01
Fe (mg/L)	N.S.	N.S.	N.S.	–	N.S.	N.S.	N.S.	N.S.	N.S.
Mn (mg/L)	N.S.	N.S.	N.S.	N.S.	–	N.S.	N.S.	N.S.	N.S.
SO_4 (mg/L)	N.S.	N.S.	N.S.	N.S.	N.S.	–	r_s = 0.755*, p < 0.05	N.S.	N.S.
NO_3 (mg/L)	r_s = -0.743*, p < 0.05	N.S.	N.S.	N.S.	N.S.	r_s = 0.755*, p < 0.05	–	N.S.	N.S.
NO_2 (mg/L)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	–	r_s = -0.737*, p < 0.05
The presence of coliform	N.S.	N.S.	r_s = 0.850**, p < 0.01	N.S.	N.S.	N.S.	N.S.	r_s = -0.737*, p < 0.05	–

Key symbols: SU: standard unit, N.S.: not significant, r_s: Spearman's rank correlation.

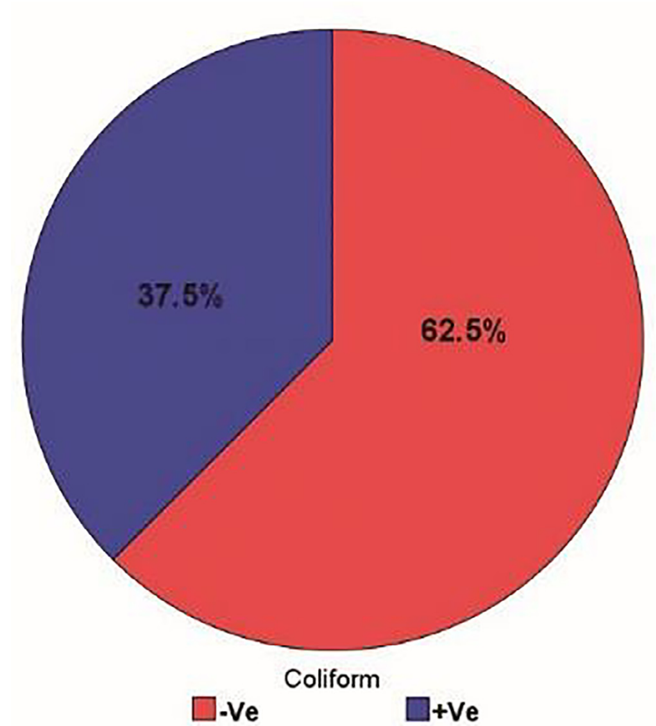

Fig. 4. Percentage of coliform presence in individual sites in some dams in Albaha region, Saudi Arabia during 2017.

by Saudi and WHO standards. Also, 2 sites (25% of the total dams) show severe values of Mn adapted by FAO standards (se. > 8 SU).

3.3. Microbiological parameter of dams' water

Screening analysis revealed that 37.5% of dams are polluted with coliform bacteria (Table 3 and Fig. 4).

3.4. Effects of spatial distribution on the variation of physico-chemical parameters

Geological processes, as well as human activities, play an important role in the variation of physico-chemical properties of water (Carpenter et al., 1998). One –Way ANOVA analysis showed no significant effects of sites either individually or as groups on the variation of the assessed parameters.

3.5. Relationships between physico-chemical parameters

Correlations between all physical, chemical and bacteriological parameters are presented in table 4 and Fig. 5. Of note, the pH was negatively correlated with NO_3 ($r_s = -0.743$) (Fig. 5A). On the other hand, SO_4 was positively correlated with NO_3 ($r_s = 0.755$) (Fig. 5B). Strong positive correlation was also found between coliform bacteria and turbidity ($r_s = -0.850$) (Fig. 5C). In contrast, the presence of coliform bacteria was negatively correlated with NO_2 (r_s = -0.737) (Fig. 5D).

4. Discussion

Total dissolved solids (TDS) include inorganic salts, such as bicarbonates, sodium and chlorides and also some dissolved organic matter. Increased TDS levels in drinking water do not necessarily reflect a health hazard. However, it may be a sign of chemical pollution (Muigai et al., 2010). Such pollution may be a small part of large hazardous pollution involving harmful organic compounds and xenobiotic chemicals especially in water bodies near intense agricultural and industrial activities (Jayaswal et al., 2018; Schwarzenbach et al., 2010). The extreme increase in TDS level may be attributed to human activities and agricultural practices around dams that can reach the reservoir of the dam, especially after rainfall events.

The Physical, chemical and bacterial properties of water can be highly affected by its turbidity (WHO, 2004). The presence of different materials, such as nutrients, clay, silts, and suspended solids result in increased turbidity especially after rainfall depositions into dams. In Ghana, Bakobie found turbidity to be the only parameter that exceeded the maximum concentrations of WHO standards for drinking water quality compared with other physical and chemical parameters investigated (Bakobie et al., 2015).

Results of the pH values in this study are consistent with those reported by Bougarne (Bougarne et al., 2017) in the reservoir water of Bab Louta in Morocco and also in another study in Jordan (Al-Khashman et al., 2017). Indeed, changes in the pH values can occur due to variations of carbon dioxide, carbonate, and bicarbonate (Agbaire and Oyibo, 2009; Al-Khashman et al., 2017). Consequently, pH variations in water affect water quality, such as solubility and toxicity of metals (Ayoade and Agarwal, 2012). Moreover, disinfection processes of water can result in higher pH values, while corrosion can drop the values into the acidic range (Trivedi et al., 2009). Similar results, in this study, of iron (Fe), sulfate (SO_4), and Nitrite (NO_2) were obtained by Gulumbe (Gulumbe et al., 2016) in Aliero dam water in Nigeria, and also by Bahroun & Chaib (Bahroun and Chaib, 2017) in dam reservoir Mexa in the northeast of Algeria. Regarding nitrate level, the results of this work are in agreement with those obtained by Abdelali who found that all values of NO_2 in Beyler Dam Lake were below the permitted levels of the surface water quality regulations (Abdelali et al., 2018).

Agriculture activities, human waste as well as animal compost may be the main cause of an increase in NO_3 at site 8 (129.30 mg/L). In general, these results are consistent with the previous report from Nigeria and Iraq (Al-Hasawi et al., 2018; Mustapha, 2008). The full oxidation of organic matter in water can be indicated by the amount of nitrate (NO_3) (Al-Hasawi et al., 2018). In water sources, nitrification processes can produce nitrate and nitrite (Xia et al., 2004). They come also from different sources, such as agricultural practices and wastewater (Thakur and Medhi, 2019).

The study of water quality of Saralasagar reservoir in India which was carried out by Reddy (Reddy and Parameshwar, 2016) found that all physical and chemical parameters including iron (Fe) were within the permissible limits given by global standards. Iron (Fe) and Manganese (Mn) are two metals that can be introduced to dams from their natural sources (rocks and soils) and/or agricultural activities in nearby areas. They cause an adverse impact on water quality and its palatability such as metallic taste and odor (Betancourt et al., 2010). Moreover, high levels of Mn can enhance the growth of bacterial biofilms in water bodies (Betancourt et al., 2010; Ljung and Vahter, 2007). A worth noting point is that Mn levels tend to increase at the bottom of the reservoirs where oxygen is limited (Betancourt et al., 2010; Htiti et al., 2015).

The total coliform test has long been used as an indicator for fecal contamination of water (APHA, 2012; 1998). However, subsequent studies observed that coliform bacteria except *E. coli* can be isolated from a natural environment devoid of any fecal materials (Doyle and Erickson, 2006). Viable count of coliform bacteria in drinking water must be 0 per 100 mL (RCER, 2015; WHO, 2017). The coliform bacteria and *E. coli* in dams found in this work may be attributed to the deposition of animal compost and fecal mate-

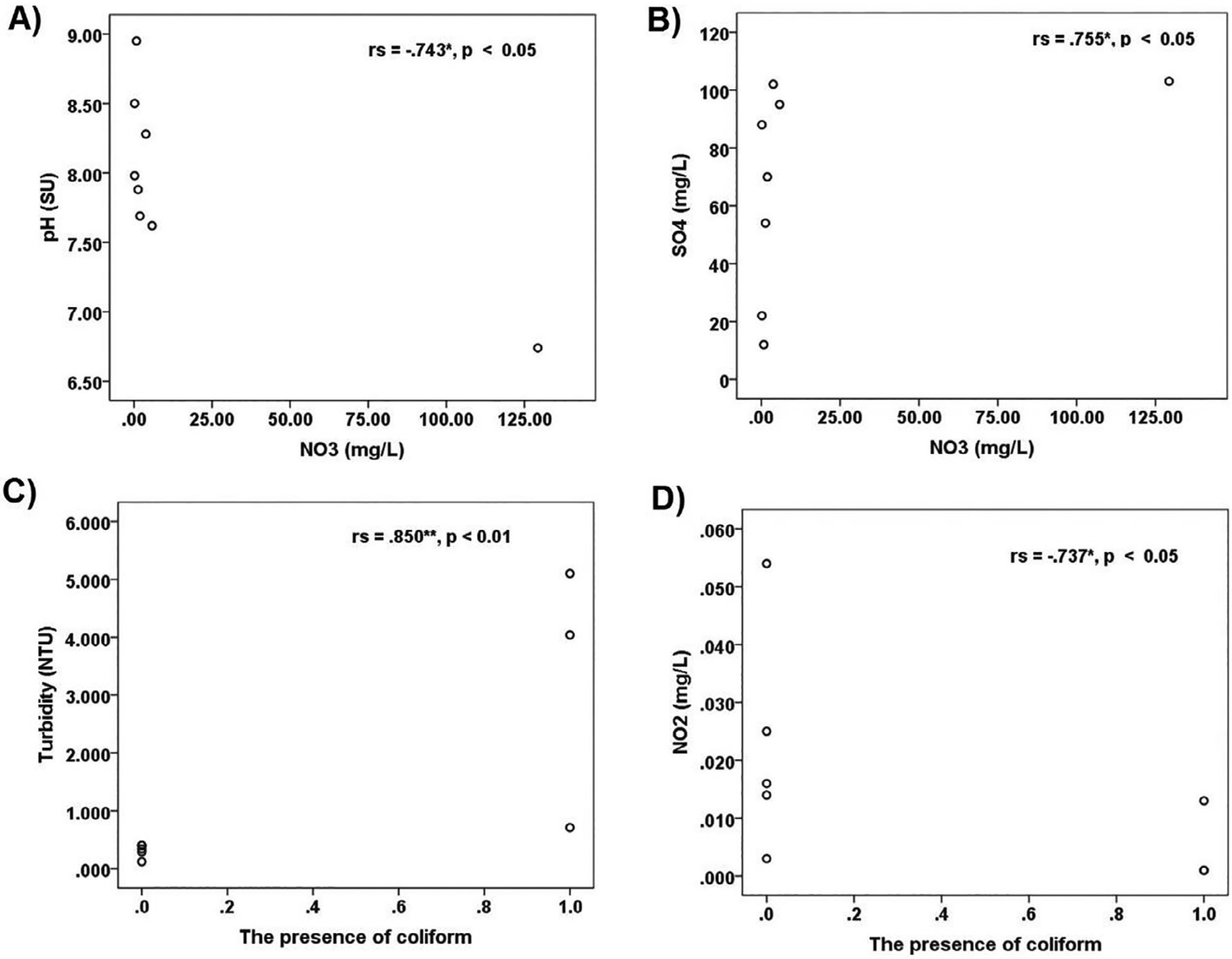

Fig. 5. Correlations between Physico-chemical parameters of dams 'water in Albaha region, Saudi Arabia.

rials that enter reservoirs through runoff and flash floods. Determining the exact source of coliform bacteria found in water is a challenge to microbiologists, mostly due to the lack of reliable techniques (Malakoff, 2002; Pandey et al., 2014). The presence of coliform bacteria in drinking water is a potential health hazard. Numerous diseases can be caused by water pollution with pathogenic bacteria, such as diarrhea and gastrointestinal illnesses (Pandey et al., 2014). In the assessment of water quality of three dams in Ghana, coliform bacteria were detected (Bakobie et al., 2015). Shekha and associates found fecal coliform bacteria in all water samples collected from the Duhok reservoir in Iraq (Shekha et al., 2013).

One –Way ANOVA analysis showed no significant effects of sites either individually or as groups on the variation of the assessed parameters. These observations are in good agreement with the study of the Tehri dam reservoir in India that found the only pH that significantly differed among other physical and chemical parameters investigated (Ayoade and Agarwal, 2012). On the contrary, Aregbe (Aregbe et al., 2018) assessed spatial variations of physicochemical parameters in three dams in Nigeria and found that most parameters varied significantly between sites except hardness, biological oxygen demand (BOD) and color.

In this study, a similar result of the negative correlation between pH and NO_3 was found by Dadgar & Payandeh (Dadgar and Payandeh, 2017) in the study of the drinking water distribution system in Tabriz city. This result indicates that the more basic water, the fewer NO_3 concentrations in water. Results of the correlation between SO_4 and NO_3 were positive, which are consistent with the results of Ogrinc in the study of nitrate sources of the Ljubljansko Polije aquifer in Slovenia (Ogrinc et al., 2019).

In this study, strong positive correlation was found between coliform bacteria and turbidity High turbidity concentrations in water can affect disinfection processes giving a chance to pathogenic bacteria to survive and replicate in water (WHO, 2017). It has been found by Armah (Armah, 2014) that the total coliform bacteria parameter can be used to predict the presence of turbidity in groundwater samples in Ghana. Similar correlation between coliform bacteria and NO_2 has also been recorded by Seo in the Nakdong River in South Korea (Seo et al., 2019). To the best of the author's knowledge, the underlying cause of the negative correlation between bacteria and NO_2 is unknown. High levels of nitrite were likely the cause since NO_2 was found to inhibit active transport and oxidative phosphorylation in aerobic bacteria including *E. coli* by in vitro analyses (Philips et al., 2002; Weon et al., 2002; Yarbrough et al., 1980)

5. Conclusion

In order to use the dams' waters for drinking and irrigation purposes, they should be treated to satisfy the Saudi, WHO and FAO standards. Site 8 (Medhas dam in Almandag) showed increases in all the investigated parameters above the recommended values except pH and nitrite. No statistically significant variations of the parameters were found between individual dam sites and also sites as groups. Significant correlations were found between pH and nitrate, sulfate and nitrate, the presence of coliform bacteria and turbidity, and the presence of coliform bacteria and nitrite. The treatment of water dams in Albaha region is strongly recommended. Further assessments of water quality in terms of spatial and temporal variations are highly advised.

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Conflicts of interest

The author declares the absence of any conflicts of interest.

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Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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