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Assessment of Falaj Water Quality

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Abstract: Aflaj forms a significant water resource system in the Sultanate of Oman of which 92% is used for irrigation purposes while the rest is used for domestic works. Continous human interventions in this system are causing adverse effects on the natural flowing water quality before it can reach the end users. This research work assesses the quality of the Aflaj water system in the Wilayat of Samail, Sultanate of Oman. Also, various physical, chemical and biological parameters have been evaluated. It is concluded that the water quality is contaminated with biological content and needs proper disinfection to avoid adverse health issues in living beings.

Key words: Aflaj, water quality, health hazards, Samail, water sampling, water pollution.

Introduction

Aflaj is a traditionally built channel system that collects and transfers the ground and surface waters. It is an ancient heritage in the Sultanate of Oman for more than 2000 years. Among the 4,112 falaj (singular of aflaj) channels, only 3,017 actively supply usable water of 410×10^6 m^3 per year (Abdel Rahman and Omezzine, 1996; Al-Hatmi and Al-Amri, 2000; Al-Marshudi, 2001; Sutton, 1984). Ghaily, Daudi, and Ainy are three types of aflaj systems in Oman and Daudi forming a major source of water in many regions. A falaj is a long channel that carries water from the source, often built with a slope for natural water flow without any mechanical pumping. Aflaj naturally flows from hilly mountains down towards villages, where the people use the water for irrigation and drinking purpose. Aflaj systems are arranged to fulfil the purpose of domestic use, which is primary followed by agricultural, which is secondary. Of the total Aflaj water, 99.8 % is used in agriculture. In most cases, aflaj water is first allocated for drinking and then used by mosques, forts, and finally domestic needs. Thereafter, falaj water is used for irrigating the permanently cultivated lands, mostly date palms, and then the seasonally cultivated lands (Al-Ghafri, 2018).

Samail is a wilayat (town) in the Al dakhiliyah region of the Sultanate of Oman with a population of approximately 60,000. Aflaj system is used for irrigation and drinking purposes (Al-Gafria et al., 2003; Al-Marshudi, 2001; Al-Rawas et al., 2000). The assessment of water quality is a tricky process as different standards have different uses. Water quality plays a significant role in evaluating the sustainable development of the region (Chenini and Khemiri, 2009). Water quality is generally assessed through biological, chemical, and physical attributes. The increase in water consumption will lead to a rapid increase in wastewater disposals. The continuous wastewater disposal back to the water body causes a serious impact on water quality (Morsy et al., 2020). An increase in the exploitation of water resources, precipitation, erosion, weathering of crustal

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materials also degrades the quality of water (Salam et al., 2019). Al-Kalbani et al. (2016) assessed the aflaj water quality in Al Jabal Al Akhdar, Oman. In this region, the quality parameters of the selected aflaj water indicated their suitability for irrigation as most of the quality parameters were within the permissible limits of Omani standards. Ghrefat et al. (2011) researched water quality mapping, assessment, and weathering processes of selected aflaj systems in Oman without any emphasis on biological content. The assessment of microbial contamination is an essential parameter for drinking water quality. The use of bioanalytical tools is rapidly increasing to assess the quality of water. Bioanalytical responses are caused by the combined action of all bioavailable mixtures, which overcomes the limitations in the water quality assessment through chemical analysis (De Baat et al., 2020). In our present research, water samples from 10 falaj channels in the wilayat of Samail area (located 65 km from Muscat) are exclusively analysed. The results are compared to the World Health Organization (WHO, 2011), GCC Standardization Organization (GSO, 2014) and Omani Standards (2012) to assess the quality of water for drinking and irrigation purpose.

Materials and Methods

Water samples were collected from 10 falaj channels in the wilayat of Samail as shown in Table 1. Wilayat Samail is situated about 65 km south of the capital city, Muscat, Sultanate of Oman. Figure 1 shows the geographical location of this research study. All the water samples were collected in preserved glass bottles and were analysed within 24 hours of sampling using the laboratory facilities at the National University of Science and Technology and Ministry of regional municipality and water resources (MRMWR), Sultanate of Oman.

Electrical conductivity (EC) and pH values were measured directly on the site using portable conductivity and pH meter. Various parameters (pH, electrical conductivity [EC], total dissolved solids [TDS], total hardness, total alkalinity, bicarbonate [HCO_3^-]), cations (calcium [Ca^{2+}], magnesium [Mg^{2+}], sodium [Na^+], potassium [K^+]), anions (sulfate [SO_4^{2-}], nitrite [NO_2^-], nitrate [NO_3^-], chloride [Cl^-], fluoride [F^-]), trace metals (vanadium, chromium, lead, cobalt, cadmium, nickel, copper, iron, molybdenum, boron, aluminum, manganese, zinc) and biological content (*E. coli* and coliforms) were evaluated according to standard procedures.

The IDEXXQC Test kit was used to identify the presence and the concentration of the biological content (*E. coli* and Coliforms). The results were expressed in the most probable number per 100 ml of water (MPN/100 ml). The concentration of HCO_3 was determined in the laboratory by titration with 0.01 M HCl using methyl-orange as an indicator. Anions (Br, F, Cl, NO_3, and SO_4) were analysed by ion chromatography (Dionex ICS-2000). Cations (Ca, Mg, Na, K, and Mn) and trace metals were measured by inductively coupled plasma spectroscopy (Perkin Elmer Avio 200 ICP-OES). The analytical precision was maintained by running a known standard after every five samples. The water hardness was calculated from Ca and Mg.

Table 1: Water samples from falaj

Falaj Name	*Number*
Al Mehedth	F1
Al Haily	F2
Al Farski	F3
Gaze Dahyah	F4
Al Blaad	F5
Al Faljat	F6
Al Tahat	F7
Al Hobe	F8
Lezuq	F9
Qurry	F10

Results and Discussion

Biological Content in Falaj Water

The biological contamination (Coliforms and *E. coli*) of individual falaj water is shown in Figure 2. All falaj water except Gaze Dahyah (F4) were contaminated with biological content. The faecal matter was found to be higher than WHO (0 MPN/100 ml), GSO (0 MPN/100 ml), and Omani un-bottled drinking water standards (total Coliforms less than 10 MPN/100 ml and *E. coli* 0 MPN/100 ml). Bacteria enter into water streams through animal and human waste and may cause health hazards such as diarrhoea, urinary tract infections, respiratory illness, pneumonia and other complex health issues. Hence, except Gaze Dahyah (F4), falaj water in all areas should be properly disinfected and monitored.

pH Variation in Falaj Water

Figure 3 shows the variation of pH in individual falaj, which is alkaline with the highest measure being 8.45 in the Al Mehedth falaj (F1). Water from all falaj was

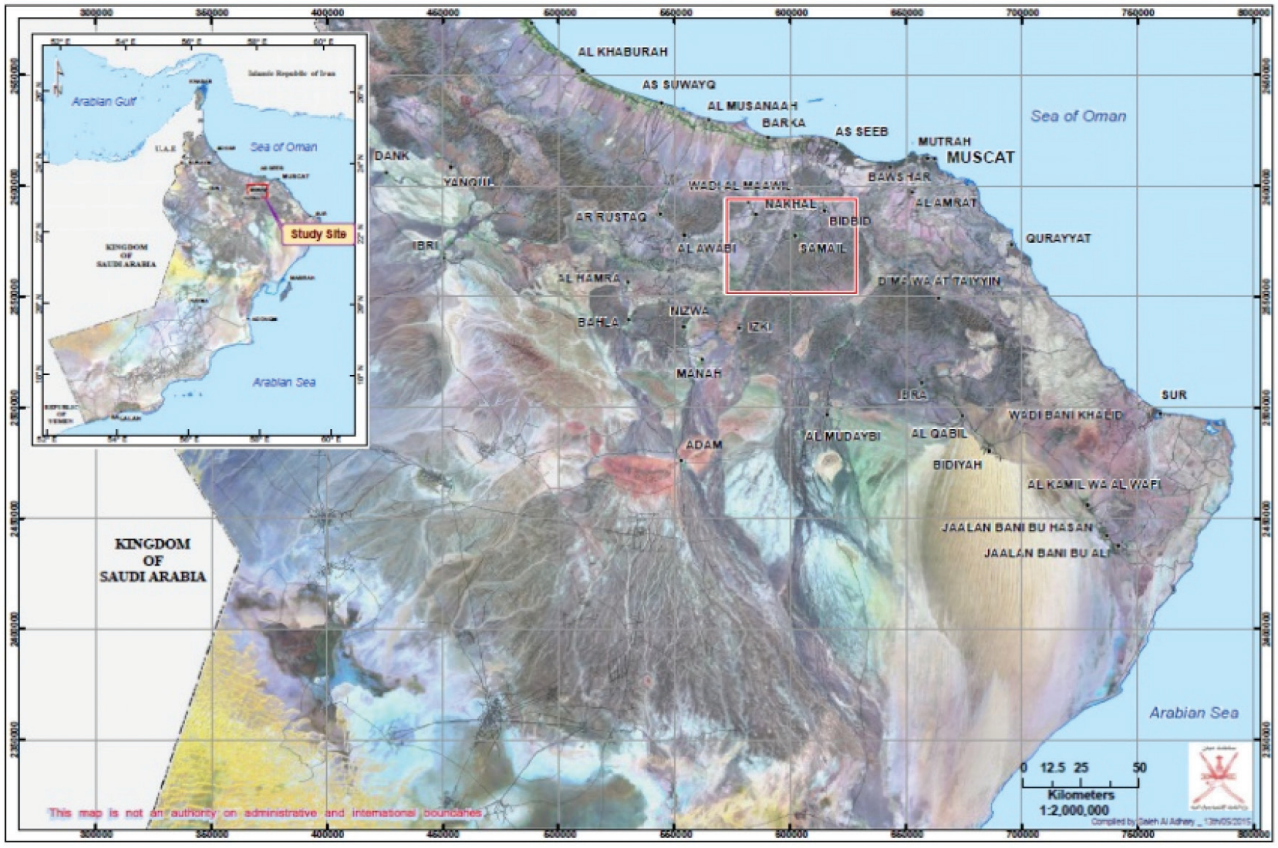

Figure 1: Geographical location of the research study.

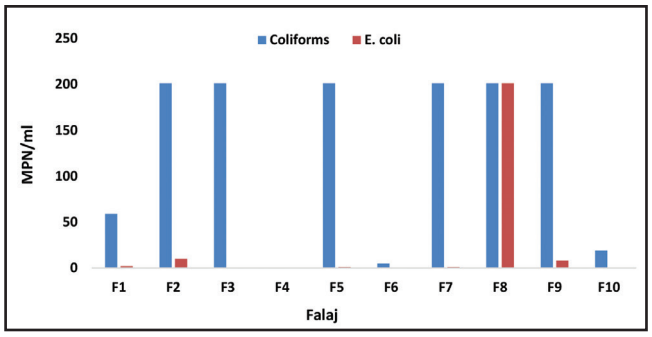

Figure 2: Biological content variation in falaj water.

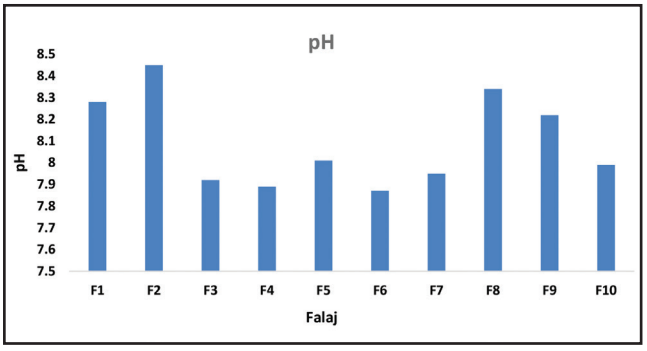

Figure 3: pH variation in falaj water.

within the permissible limits of WHO (6.5-8.5), GSO (6.5-8.5) and Omani un-bottled drinking water (9.0) standards.

Variation of Physical Parameters in Falaj Water

Figure 4 shows the variations of physical parameter concentrations in individual falaj water. The allowable limits as per standards are shown in Table 2. EC, TDS, bicarbonate, total hardness of falaj water were within the permissible limits of WHO, GSO and Omani standards. Qurry (F10) falaj water was bit saline as compared to other falaj water within the same wilayat with high EC (1257.88 µS/cm) and TDS (744.58 mg/L). Al Faljat (F6) and Qurry (F10) falaj water showed high bicarbonate, 357.12 mg/L and 341.09 mg/L, respectively, which indicates the presence of dolomite rocks. The is also substantiated by the high concentration of Mg (Figure 5) in the falaj waters. Total alkalinity was slightly higher than the allowable limits in Al Farski (F3), Al Faljat (F6) and Qurry (F10) falaj water. The main concerns assumed are that excess alkalinity may lead to gastrointestinal and metabolic alkalosis problems. Therefore, proper monitoring and control of alkalinity are recommended.

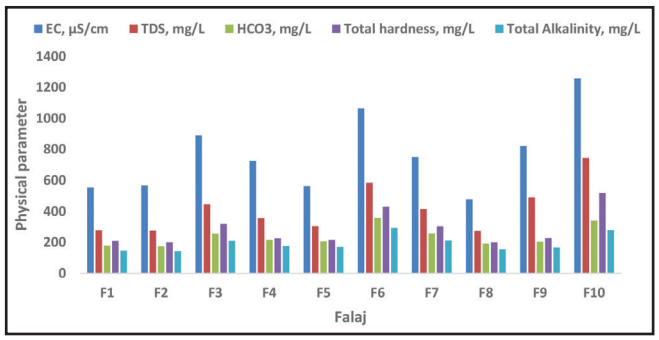

Figure 4: Physical parameter variation in falaj water.

Table 2: Physical parameters standards

Parameter	*WHO(2011)*	*GSO(2014)*	*Omani(2012)*
Electrical conductivity (EC), µS/cm	400-1500	1500	184-1538
Total dissolved solids (TDS), mg/L	1000	100-1000	120-1000
Bicarbonate (HCO_3^-), mg/L	500	500	500
Total hardness, mg/L	500	500	200-500
Total alkalinity, mg/L	120-200	120-200	120-200

Variation of Cation Concentration in Falaj Water

The cation concentration variations in individual falaj water are shown in Figure 5 and standards in Table 3. It was seen that calcium and sodium were below the permissible limits of WHO, GSO and Omani standards. Potassium guideline value not defined in GSO and Omani standards. Magnesium in Al Mehedth (F1), Al Haily (F2), Al Farski (F3), Al Tahat (F7) and Lezuq (F9) were slightly above permissible limits. Al Faljat (F6) and Qurry (F10) had high magnesium content. Drinking water with high magnesium content may result in diarrhoea and laxative effect in human beings.

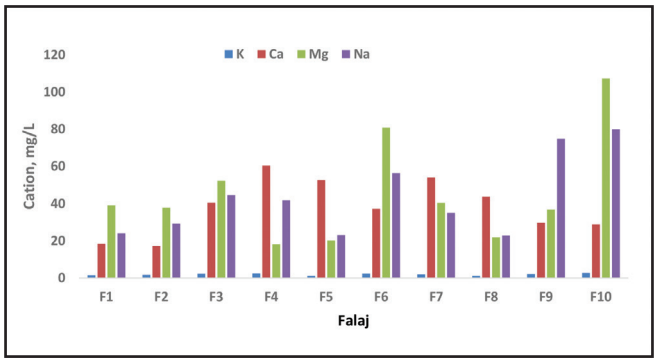

Figure 5: Cation concentration in Aflaj water.

Therefore, the concentration of magnesium needs control with suitable treatment technology.

Table 3: Cation concentration standards

Parameter	*WHO(2011)*	*GSO (2014)*	*Omani (2012)*
Potassium (K^+), mg/L	12	-	-
Calcium (Ca^{2+}), mg/L	75	75	75
Magnesium (Mg^{2+}), mg/L	30	30	30-150
Sodium (Na^+), mg/L	150	150	250-400

Variation of Anion Concentration in Falaj Water

Anion concentration in individual falaj water samples is shown in Figure 6 and standards in Table 4. Fluoride, chloride and sulfate were present at lower values than the allowable WHO, GSO and Omani standards. Silicate guideline, not defined. Al FArski (F3), Al Blaad (F6), Lezuq (F9) and Qurry (F10) had higher concentrations of nitrite. In addition to nitrite, the concentration of nitrate was also high in Lezuq (F9) and Qurry (F10)

Table 4: Anion concentration standards

Parameter	*WHO(2011)*	*GSO(2014)*	*Omani(2012)*
Fluoride (F^-), mg/L	1.5	1.5	1.5
Chloride (Cl^-), mg/L	250	250	250-600
Nitrite (NO_2^-), mg/L	3	3	3
Nitrate (NO_3^-), mg/L	50	50	50
Sulfate (SO_3^-), mg/L	250	250	250-400
Silicate (Si^-), mg/L	-	-	-

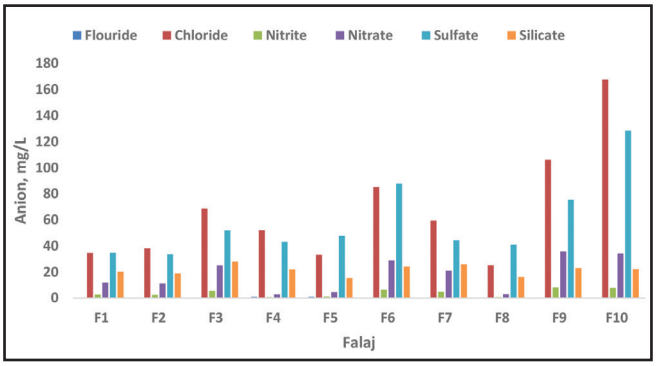

Figure 6: Anion concentration in Aflaj water.

falaj water as compared to the standard allowable limits. Contamination of falaj water with human and animal waste, pesticides and fertilisers leads to a rise in nitrate concentration and hence proper monitoring and control mechanism is recommended.

Variation of Trace Metal Concentration in Falaj Water

Trace metal concentration variation in individual falaj water is shown in Figures 7 and 8. WHO, GSO and Omani standards are almost the same for trace metal concentration in drinking water (Table 5). Trace metals below the allowable limits was found in falaj water.

Table 5: Standards for trace metals in water

Trace metal	*WHO(2011)*	*GSO(2014)*	*Omani(2012)*
Vanadium, mg/L	-	-	-
Chromium, mg/L	0.05	0.05	0.05
Lead, mg/L	0.01	0.01	0.01
Cobalt, mg/L	-	-	-
Cadmium, mg/L	0.003	0.003	0.003
Nickel, mg/L	0.07	0.02	0.02
Copper, mg/L	1.0	2.0	2.0
Iron, mg/L	0.2	1.0	1.0
Molybdenum, mg/L	0.07	0.07	0.07
Boron, mg/L	2.4	2.4	0.5-2.4
Aluminum, mg/L	0.2	0.1-0.2	0.1-0.2
Manganese, mg/L	0.4	0.4	0.4
Zinc, mg/L	5.0	3.0	3.0

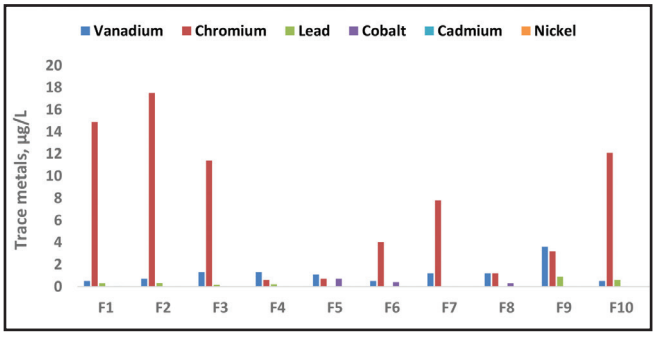

Figure 7: Trace metals concentration variation in falaj water.

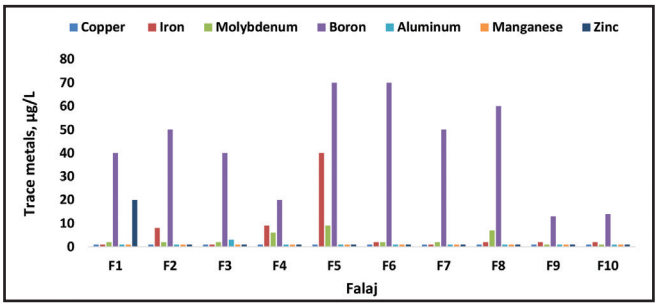

Figure 8: Trace metals concentration variation in falaj water.

Sodium absorption ratio (SAR) is a critical factor for irrigation purposes. Table 6 shows the salinity and sodium hazard in individual falaj water based on Wilcox (1955) salinity diagram. Al Farski (F3), Al Faljat (F6), Al Tahat (F7), Lezuq (F9) and Qurry (F10) falaj water showed high salinity hazard and the rest were at medium level. Sodium hazard ranged from medium to low in all falaj water.

Table 6: Salinity and Sodium Hazards for Falaj Water

Falaj name	*SAR*	*Salinity hazard*	*Sodium hazard*
Al-Mehedth	4.49	Medium	Low
Al-Haily	5.57	Medium	Medium
Al-Farski	6.54	High	Low
Gaze Dahyah	6.68	Medium	Medium
Al-Blaad	3.83	Medium	Medium
Al-Faljat	7.35	High	Low
Al-Tahat	5.11	High	Low
Al-Hobe	4.01	Medium	Low
Lezuq	12.98	High	Medium
Qurry	9.69	High	Low

Conclusions

It is concluded that the water quality assessment from the individual falaj in wilayat Samail is not suitable for drinking and domestic usage because of microbial contamination except for Gaze Dahyah falaj. Hence, due to liquid and solid sewage wastes from the houses, proper disinfection or control of contamination of falaj water is required. Other than biological contamination, all other parameters including trace metals were within the allowable limits of WHO, GSO and Omani standards. The study shows that the usage of falaj water for irrigation purposes was quite suitable.

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