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International Journal of Current Research
Vol. 9, Issue, 12, pp.62212-62215, December, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

WATER QUALITY INDEX AND ITS VARIATION AMONG AFLAJ WATER RESOURCES IN NIZWA AREA-A CASE STUDY

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ARTICLE INFO

Article History:
Received 16th September, 2017
Received in revised form
06th October, 2017
Accepted 22nd November, 2017
Published online 27th December, 2017

Key words:
Daris, Falaj,
Water Quality Index,
Nizwa.

ABSTRACT

In Oman the annual average rain fall is 100mm. Falaj is an open water channel developed some 2000 years back. It originates from a mother well and flows under gravity. Two or more Falaj water streams are called Aflaj. In Oman, more than 3000 falajs water streams are flowing to cater drinking and irrigation need. The aim of this article is to estimate water quality in three falajs water streams in Nizwa area and to calculate water quality index for each stream. Three samples were collected from each falaj and analyzed for total dissolved solids, calcium, total alkalinity, chloride, sulphate, nitrate and total hardness. Water quality index was calculated for each sample and average of three samples taken for assessment. It was observed that the average WQI for Falaj Daris is 57, Falaj Al-Khatmayn is 47 and Falaj Al-Muyassar is 78. It was observed that the water quality for Falaj Al-Khatmayn is excellent and water quality for Falaj Daris and Falaj Al-Muyassar are good and acceptable for drinking purpose after proper disinfection.

Citation: Sathiraju Venkata Satyanarayana, Natiq Joodi, Hatem Yazdi, 2017. "Water quality index and its variation among aflaj water resources in nizwa area-a case study", *International Journal of Current Research*, 9, (12), 62212-62215.

INTRODUCTION

Nizwa is the Islamic capital of Oman. Falaj Daris in Nizwa area was in the UNESCO list (United Nations Educational Scientific and Cultural Organization). Due to rapid urbanization and population growth, it is necessary to assess the water quality of falaj water open channels flow at regular intervals. The most effective way of consolidating all the parameters of water samples are quality indices (Abdul Hameed, 2010). This helps to know the quality of water with the help of a single index instead of comparing all the parameters and their standards. Water quality index is a mathematical tool to integrate all parameters into a numerical score (Sanjib Das *et al.,* 2013; Tahera Akter1 *et al.,* 2016). The WQI summarizes all parameters in to a single value (Ochir Altansukh1, 2011). Seasonal variations plays a major role on quality of surface water. During summer months, due to increased temperature and reduced water flow the water quality changes (https://www.mwa.co.th/do wnload/file_u pload/SMWW_1000-3000.pdf). Surface water contamination is due to unplanned urbanization (Devendra Dohare1 *et al.,* 2014).

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If the WQI is high that means some parameters are above the permissible limit (Gopal Krishan *et al.,* 2016). It is necessary to investigate the source of pollution. The municipal solid waste dump sites are contributing for water contamination (Ilaboya *et al.,* 2014). Sodium Absorption Ratio (SAR) value gives an idea whether the water is suitable for agricultural purpose or not (Ishaku, 2012).

MATERIALS AND METHODS

Three samples each collected from Falaj Daris, Falaj Al-Khatmayn and Falaj Al-Muyassar. The samples were analyzed for Total Dissolved Solids (TDS), calcium, total alkalinity, chloride, sulphate, nitrate and total hardness. The samples were analyzed by using Standard Methods for the Examination of Water and Wastewater (https://www.mwa.co.th/download /file_upload/SMWW_1000-3000.pdf). The analysis were tabulated in Table 1.

Water Quality Index (WQI)

The WQI is a management tool and is defined as rating of different water quality parameters and their suitability for human consumption (Pathak *et al.,* 2015). WQI was used by Horton in 1965.

Different methods are available to calculate WQI. Initially sub index Qi is calculated by using the below formula.

$Qi = Ci/Si \times 100$

Where Qi = sub–index.

Ci = water quality analysis for the i th parameter.
The value is obtained from the Table-1
Si is the maximum permissible standard value for the i th parameter.

$WQI = \sum Qi*Wi / \sum Wi$

Where WQI = water quality index

Wi = 1/Si

Three samples each from Fajaj Daris, Falaj Al-Khatmayn and Falaj Al-Muyassar were collected and analyzed for TDS, Calcium, Total Alkalinity, Chloride, Sulphate, Nitrate and Total Hardness. The values are shown in Table-1.

Table 1. Water quality analysis of Falaj Daris, Falaj Al-Khatmayn and Falaj Al-Muyassar

Parameter	Sample-1	Sample-2	Sample-3
Falaj Daris-Ci values			
TDS mg/L	342	346	350
Calcium mg/L	57	60	62
Total Alkalinity mg/L	170	172	174
Chloride mg/L	50	50	50
Sulphate mg/L	35	35	36
Nitrate as NO3 mg/L	21	21	22
Total Hardness mg/L	274	283	287
Falaj Al-Khatmayn- Ci values			
TDS mg/L	310	322	315
Calcium mg/L	60	62	63
Total Alkalinity mg/L	157	168	165
Chloride mg/L	30	31	28
Sulphate mg/L	56	53	54
Nitrate as NO3 mg/L	9	10	10
Total Hardness mg/L	251	257	287
Falaj Al-Muyassar- Ci values			
TDS mg/L	417	413	416
Calcium mg/L	59	59	57
Total Alkalinity mg/L	213	207	208
Chloride mg/L	43	43	45
Sulphate mg/L	45	45	46
Nitrate as NO3 mg/L	41	41	41
Total Hardness mg/L	316	316	315

The water quality analysis of Fajaj Daris, Falaj Al-Khatmayn and Falaj Al-Muyassar for all the three samples were shown graphically in Fig 1, Fig 2 and Fig 3.

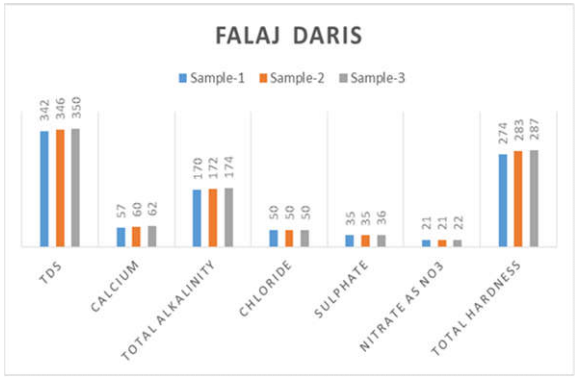

Fig. 1. Water quality analysis of falaj daris

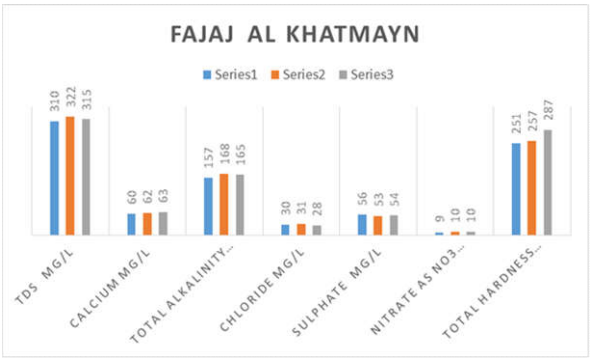

Fig 2. Water quality analysis of Falaj Al Khatmayn

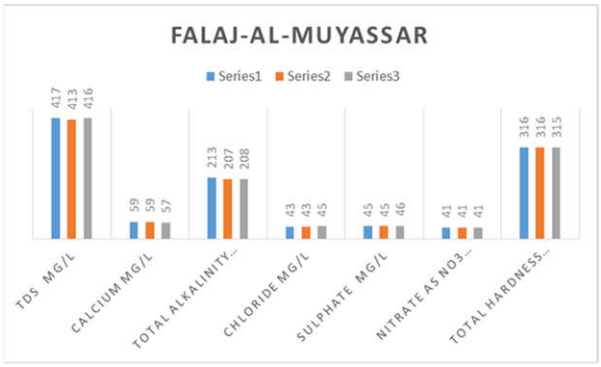

Fig. 3. Water quality analysis of Falaj Al Muyassar

The standards for drinking water quality are given as given in table 2:

Table 2. Drinking water specifications

S. No.	Substance or Characteristic	(Desirable Limit)
Essential characteristics		
1.	Color, (Hazen units), Max	5
2.	Odor	Unobjectionable
3.	Taste	Agreeable
4.	Turbidity (NTU), Max	5
5.	pH Value	6.5 to 8.5
6.	Total Hardness (as $CaCo_3$) mg/L, Max	300
7.	Iron (as Fe) mg/L, Max	0.3
8.	Chlorides (as Cl) mg/L, Max.	250
9.	Residual, free chlorine, mg/L, Min	0.2
10.	Fluoride (as F) mg/L, Max	1.0
Desirable Characteristics		
11.	Total Dissolved solids mg/L, Max	500
12.	Calcium (as Ca) mg/L, Max	75
13.	Magnesium (as mg) mg/L, Max	30
14.	Copper (as Cu) mg/L, Max	0.05
15.	Manganese (as Mn)mg/L, Max	0.10
16.	Sulfate (as SO_4) mg/L, Max	200
17.	Nitrate (as NO_3) mg/L, Max	45
18.	Phenolic Compounds (as C_6H_5OH) mg/L, Max	0.001
19.	Mercury (as Hg) mg/L, Max	0.001
20.	Cadmium (as Cd) mg/L, Max	0.01
21.	Selenium (as Se) mg/L,Max	0.01
22.	Arsenic (as As) mg/L, Max	0.01
23.	Cyanide (as CN) mg/L, Max	0.05
24.	Lead (as Pb) mg/L, Max	0.05
25.	Zinc (as Zn) mg/L, Max	5
26.	Anionic detergents (as MBAS) mg/L, Max	0.2
27.	Chromium (as Cr^{6+}) mg/L, Max	0.05
28.	Poly nuclear aromatic hydrocarbons (as PAH) g/L, Max	--
29.	Mineral Oil mg/L, Max 0.01	0.01
30.	Pesticides mg/L, Max	Absent
31.	Radioactive Materials	
	i. Alpha emitters Bq/L, Max	--
	ii. Beta emitters pci/L, Max	--
32.	Alkalinity mg/L, Max	200
33.	Aluminum (as Al) mg/L, Max	0.03
34.	Boron mg/L, Max	1

(Source: BIS Specifications for drinking water quality)

RESULTS AND DISCUSSIONS

The Water Quality Index for Falaj Daris varied from 56 to 59. The index falls in the good quality. It was not affected by the latest landscaping and urbanization of Nizwa city. The WQI for Falaj Al-Khatmayn varies from 45 to 48.The index falls in the excellent category.

Table 6. Water Quality Index Rating

Water Quality Index	Rating
< 50	Excellent
50 - 100	Good Quality
100 - 200	Poor Quality
200 - 300	Very Poor Quality
>300	Unfit for human consumption.

Table 3. Water Quality Index of Falaj Daris

Parameter	Qi1=Ci1/Si * 100	Qi2=Ci2/Si * 100	Qi3=Ci3/ Si * 100	Wi = 1/Si	Qi * Wi-1	WQI=∑ Qi*Wi/∑ Wi	Qi * i-2	WQI-2	Qi * Wi-3	WQI-3
TDS	68.4	69.2	70	0.002	0.1368		0.1384		0.14	
Calcium	76	80	83	0.013	0.988		1.04		1.079	
Total Alkalinity	85	86	87	0.005	0.425		0.43		0.435	
Chloride	20	20	20	0.004	0.08		0.08		0.08	
Sulphate	17.5	17.5	18	0.005	0.0875		0.0875		0.09	
Nitrate as NO3	47	47	49	0.022	1.034		1.034		1.078	
Total Hardness	91	94	96	0.003	0.273		0.282		0.288	
				0.054	3.0243	56	3.0919	57	3.19	59

Table 4. Water Quality Index of Falaj Al-Khatmayn

Parameter	Qi1=Ci1/Si * 100	Qi2=Ci2/Si * 100	Qi3=Ci3/Si * 100	Wi = 1/Si	Qi * Wi-1	WQI=∑ Qi*Wi/∑ Wi	Qi* Wi-2	WQI-2	Qi * Wi-3	WQI-3
Theoretical TDS	62	64.4	63	0.002	0.124		0.1288		0.126	
Calcium	80	83	84	0.013	1.04		1.079		1.092	
Total Alkalinity	78.5	84	82.5	0.005	0.3925		0.42		0.4125	
Chloride	12	12.4	11.2	0.004	0.048		0.0496		0.0448	
Sulphate	28	26.5	27	0.005	0.14		0.1325		0.135	
Nitrate as NO3	20	22	22	0.022	0.44		0.484		0.484	
Total hardness	84	86	96	0.003	0.252		0.258		0.288	
				0.054	2.4365	45	2.5519	47	2.5823	48

Table 5. Water Quality Index of Falaj Al-Muyassar

Parameter	Qi1=Ci1/Si * 100	Qi2=Ci2/Si * 100	Qi3=Ci3/Si * 100	Wi = 1/Si	Qi * Wi-1	WQI=∑ Qi*Wi/∑ Wi	Qi * Wi-2	WQI-2	Qi * Wi-3	WQI-3
Theoretical TDS	83.4	82.6	83.2	0.002	0.1668		0.1652		0.1664	
Calcium	79	79	76	0.013	1.027		1.027		0.988	
Total Alkalinity	106.5	103.5	104	0.005	0.5325		0.5175		0.52	
Chloride	17.2	17.2	18	0.004	0.0688		0.0688		0.072	
Sulphate	22.5	22.5	23	0.005	0.1125		0.1125		0.115	
Nitrate as NO3	91	91	91	0.022	2.002		2.002		2.002	
Total hardness	105	105	105	0.003	0.315		0.315		0.315	
				0.054	4.2246	78	4.208	78	4.1784	77

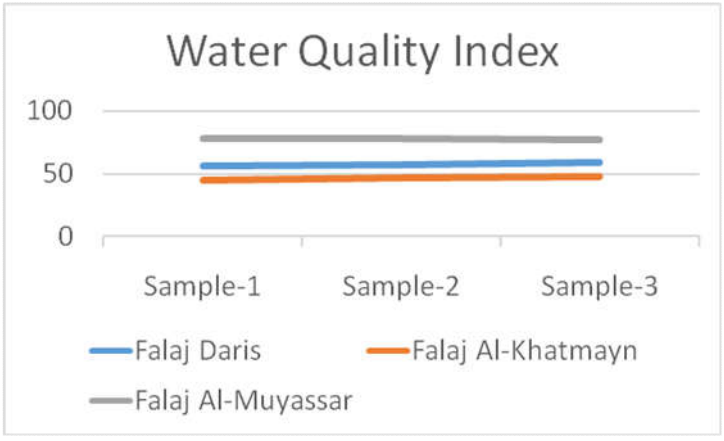

Fig. 4. Water Quality Index of Falaj Water Resources

It was unaffected by population growth and urbanization. The Water Quality Index of Falaj Al-Muyassar varies from 77 to 78. The index is in the good quality range. The details of WQI calculations for Falaj Daris were shown in Table 3. The details of WQI calculations for Falaj Al-Khatmayn were shown in Table 4. The details of WQI calculations for Falaj Al-Muyassar were shown in Table 5.

Table 7. Water Quality Index for Falaj water resources

Falaj	WQI – Sample-1	WQI – Sample-2	WQI – Sample-3	Remarks
Falaj Daris	56	57	59	Good quality
Falaj Al-Khatmayn	45	47	48	Excellent
Falaj Al-Muyassar	78	78	77	Good quality

The WQI values for Fajaj Daris, Falaj Al-Khatmayn and Falaj Al-Muyassar were shown graphically in Fig 4.

Conclusions

The falaj water resources are contributing to meet drinking and agricultural needs of Nizwa area people. Falaj Daris is in the list of UNESCO heritage sites. The water quality of falaj Daris is good. The water quality index of Falaj Al-Khatmayn remained excellent. It was observed that Falaj Al-Muyassar is slowly moving towards poor quality. There is a need to monitor the Falaj Al-Muyassar water quality at regular interval because the WQI is higher than the remaining Falaj Daris and Falaj Al-Khatmayn.

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