IMPACT OF WASTEWATER DISCHARGE ON WATER QUALITY OF KAROON RIVER IN IRAN

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ABSTRACT

Preservation of the Karoon and Dez Rivers, the fresh water resource, is of high importance in Khuzestan province with its rapid growth of population and agricultural and industrial activities. In this paper the water quality and quality conditions of four study areas are mapped, agricultural, industrial and urban pollutant sources identified, and their impact on biological, physical and chemical water quality of Karoon River examined. Twenty five quality monitoring stations were established to determine the pollution load to the Karoon and Dez Rivers. The analysis shows that wastewater discharge has different impacts on chemical and biological water quality in the four study areas, in both the short and long term.
Keywords: Dez River, Karoon River, wastewater discharge, water quality.

1 INTRODUCTION

River valleys generally constitute areas with the highest population density because of favorable living conditions such as fertile lands, water for irrigation, industrial or drinking purposes, and transportation. On the other hand, rivers play a major role in exporting and assimilating industrial and municipal wastewater, agricultural discharges, and runoff from agricultural fields, roadways and streets, which can lead to pollution of the rivers [1]. It is necessary for effective and efficient water management to have reliable information on water discharge and quality and the likely impact of pollution [2].

The Karoon River is a tributary of the Tigris–Euphrates River and has the largest drainage area in Iran. The Karoon River basin, with a basin area of 67,000 km^2, is located in southern part of Iran between longitudes 48°15′ and 52°30′ east, latitude 30°17′ and 33°49′ north. The origin of the Karoon River is 75 km south of Esfahan city in the Zagros Mountain ranges and divided into two branches, Gargar and Shatit. North of Shooshtar city, in Ghir weir, the two branches and the Dez River join each other and form a great river called the Karoon. The upstream basin occupies the highly elevated Zagros mountain range which is subject to debris flows, landslides and floods. The Karoon is Iran's largest and only navigable river. It is 450 miles (720 km) long and serves the Khuzestan province. Many urban areas, industries and agricultural sites have been located near the Karoon River basin and unfortunately, most discharge their effluent into the river, without any treatment.

The water quality index (WQI) was developed to give the criteria for surface water classification based on the use of standard parameters for water characterization [3–16]. It is a mathematical instrument used to transform large quantities of water characterization data into a single number. Estimation of the WQI requires a normalization step where each parameter is transformed into a 0–100 scale, where 100 represents the maximum quality. The next step is to apply a weighting factor in accordance with the importance of the parameter as an indicator of water quality [7, 8, 13].

Brown *et al*. [17] developed a WQI for categorizing water resource uses based on their quality. This effort was supported by the National Sanitation Foundation (NSF). For this reason Brown's index is also referred as NSFWQI [17] (the National Sanitation Foundation Water Quality Index).

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In this study, the water quality of Karoon River and its branches was assessed and monitored in 2007–2008 by the NSFWQI method and zoning quality was done for the whole river. Also, the salinity parameter was assessed for some part of Karoon River.

2 MATERIALS AND METHODS

2.1 Sampling

The Karoon River has 25 monitoring stations for both quantity and quality of river's water, 20 of them located on the Karoon River and 5 stations on the Dez River (Fig. 1, Table 1). Sampling at these

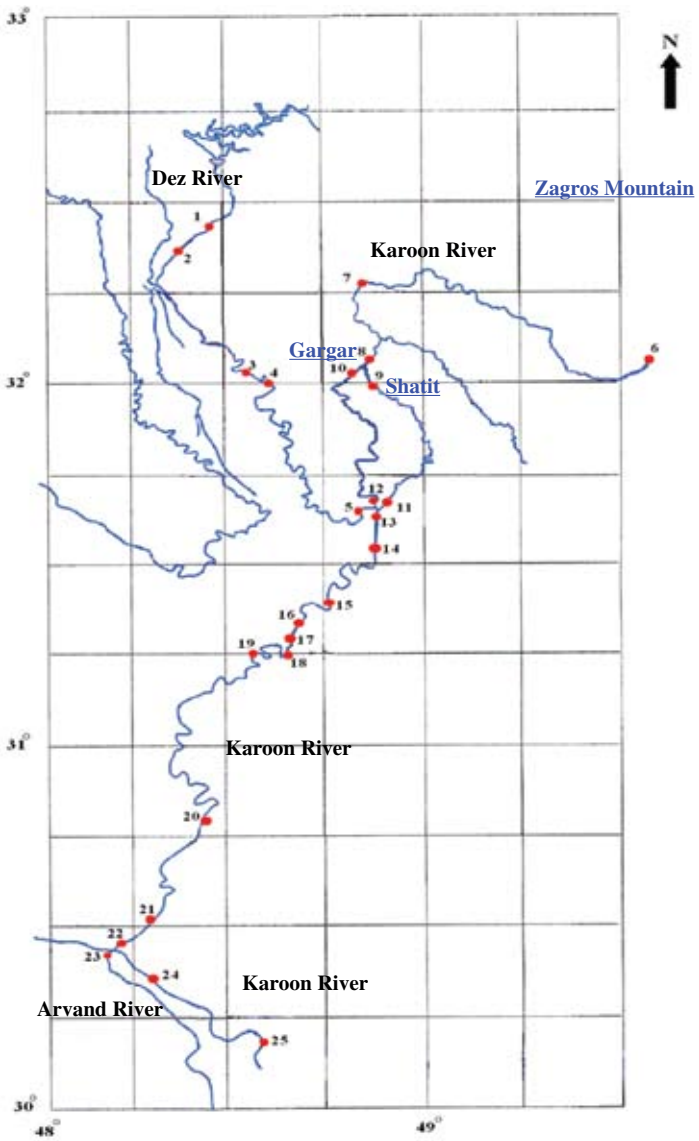


Figure 1: The Karoon River scheme, its branches and sampling station [18].

Table 1: Monitoring stations specification of Karoon River [18].

No.	Station name	Distance from source (km)	Geographical specification			Sampling period
			Longitude	Latitude	Height (m)	
Dez River						
1	Chamgalak	18	48°28′46″	32°26′47″	330	Seasonal
2	Dezful Qand Industry	44	48°20′00″	32°14′15″	350	Seasonal
3	Shirin Water	83	48°31′30″	32°02′45″	334	Seasonal
4	Mostofi	98	48°31′38″	32°01′41″	330	Seasonal
5	Dez–Ghir Weir	152	48°52′15″	31°38′45″	330	Monthly
Karoon River						
6	Abbaspour Dam	0	49°36′40″	32°01′05″	368	Seasonal
7	Gatvand Dam	153	48°49′19″	32°14′43″	375	Seasonal
8	Mizan Weir	183	48°51′50″	32°03′00″	330	Monthly
9	Shatit–Shooshtar	186	48°50′10′	32°02′50″	330	Seasonal
10	Gargar–Shooshtar	186	48°50′50″	32°02′00″	330	Seasonal
11	Shatit–Ghir Weir	265	48°52′00″	31°38′30″	320	Monthly
12	Gargar–Ghir Weir	262	48°53′15″	31°39′00″	320	Monthly
13	Karoon–Ghir Weir	267	48°52′50″	31°38′45″	320	Monthly
14	Ramin	284	48°52′30″	31°29′30″	328	Seasonal
15	Zargan	318	48°45′30″	31°24′00″	320	Monthly
16	New Side	334	48°42′00″	31°19′30″	320	Seasonal
17	Ahvaz 5th Bridge	340	48° 39′30″	31°18′00″	320	Seasonal
18	Chanibie	344	48°39′30″	31°16′10″	320	Seasonal
19	Um Al Tamir	368	48°33′35″	31°14′45″	320	Monthly
20	Darkhovein	476	48°25′00″	30°43′45″	305	Seasonal
21	Nahrmard	512	48°18′00″	30°30′00″	304	Seasonal
22	Khorramshahr Soap Industry	524	48°12′50″	30°25′30″	303	Monthly
23	Haffar	528	48°12′45″	30°26′05″	303	Monthly
24	Bahmanshir	541	48°19′30″	30°19′20″	303	Seasonal
25	Choebade	576	48°35′00″	30°11′30″	302	Monthly

stations is either seasonal or monthly. Figure 2 shows main pollutant sources around the Karoon and Dez Rivers. Most of the industries are food-related industries.

The water quality and quantity data used in this study was obtained from the Khuzestan water and wastewater company [18] and is for the period September 2007 to March 2008. The water quality parameters that are used in this study are dissolved oxygen (DO), pH, Biochemical oxygen demand (BOD_5), Temperature (T°), Turbidity, Total solids (TS), Nitrate (NO_3), Phosphate (PO_4) and Fecal coliforms (FC). Electrical conductivity (EC) and Chloride Ion (Cl^-) were also measured at 11 sampling stations near Ahvaz and Abadan cities as a means of determining the salinity of Dez and Karoon Rivers during the period September 2007 to March 2008. Analyzing of all these parameters was in accordance with the Standard methods for the examination of water and wastewater [19]. It is realized that the sampling period is short (6 months) but this study of the trends and sources of pollution did not require a more detailed and longer period of records. The period is the wet-season period for the area.

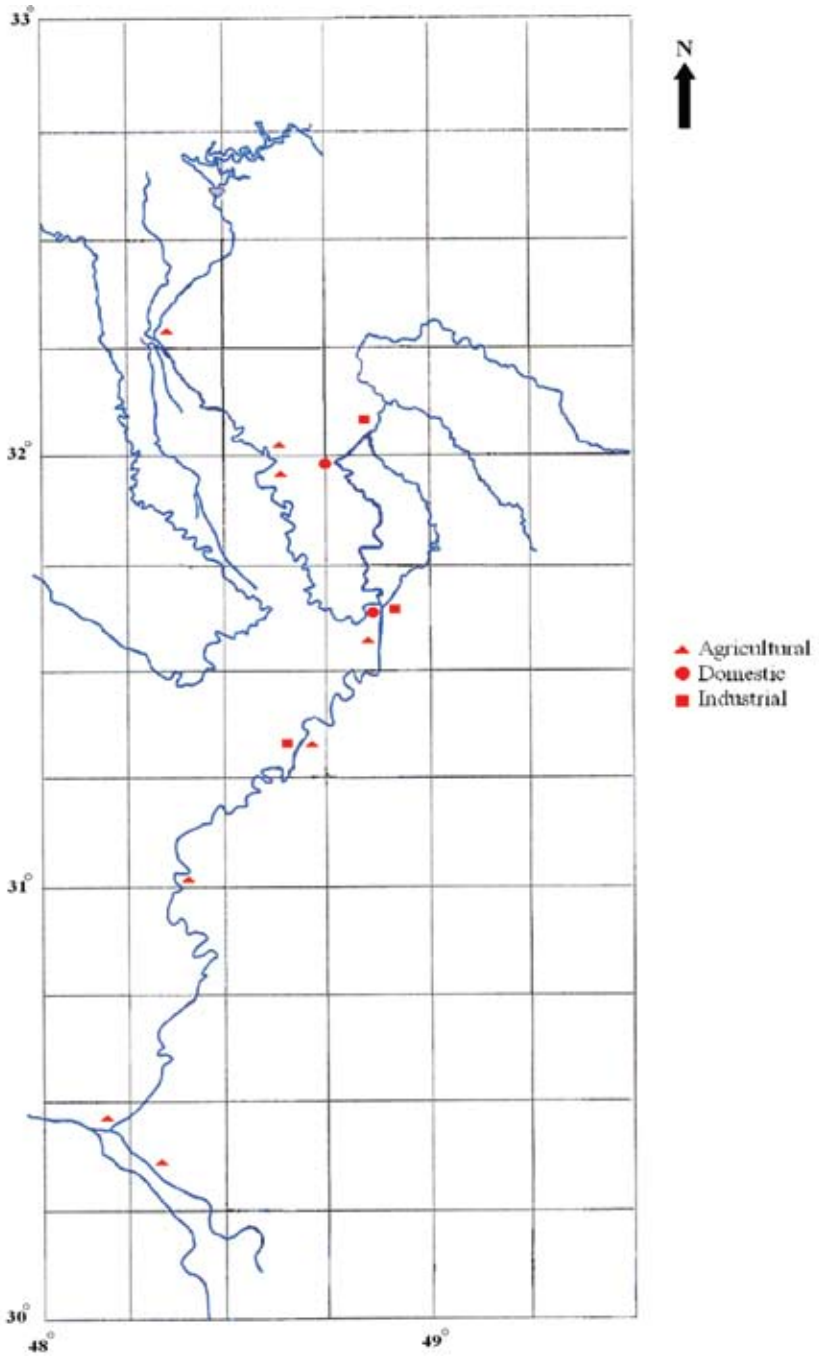


Figure 2: Main pollutant sources around Karoon and Dez Rivers [20, 23].

2.2 Data analysis

The weight factor for NSFWQI was developed using a modified version of the questionnaire of Brown *et al*. [17].

A panel of 18 persons with expertise in water quality management was formed for this study. They have been working on water resources quality management in four significant universities of Iran (Tehran, Sharif, Science and Technology, Amir Kabir). The panelists were asked to rank the NSFWQI parameters according to their significance as contributors to overall quality. The rating was done on a scale of 1 (highest) to 5 (lowest). The responses of the panel were brought to the knowledge of every member of the panel and the members were allowed to review their individual judgment in the light of the full panel's response. The weighting factors were calculated according to the following steps:

1. The responses of each rank were determined on a scale of 1 to 5;
2. The weighting average of each parameter portion was calculated;
3. The temporary weighting factor was calculated by dividing parameter portion to smallest portion and
4. Dividing the temporary weight factor of each parameter to the sum of temporary weight factors for calculating final weight factor of each parameter.

The index developed by the method of Brown *et al*. [17] is given by

$$\text{NSFWQI} = \sum_{i=1}^{n} W_i I_i \tag{1}$$

where I_i = the quality of the ith parameter (a number between 0 and 100 read from the appropriate sub-index graph) and W_i = the weight factor of the ith parameter.

However, in cases of weak sub-indices (near to zero), a modified equation was used [21]:

$$\text{NSFWQI} = \prod_{i=1}^{n} I_i^{W_i} \tag{2}$$

In this study, eqn (2) was used to assess the water quality indices based on the NSFWQI method.

The salinity parameter was determined by the EC and Cl^- monthly measurement of Karoon River near to Ahvaz and Abadan cities.

3 RESULTS

Table 2 shows the results of temporary and final weight factors of NSFWQI parameters that were concluded from the questionnaire of this study. As can be seen, these factors differ from the original NSFWQI factors. The maximum difference is about 30% for BOD_5 and temperature. Turbidity was omitted due to the low turbidity of water samples during the period of the study and an inability to fit this parameter to the NSFWQI chart. So, the temporary and final weight factors of NSFWQI parameters were recalculated without turbidity (Table 3). In Table 4, the sub-index quantities of quality factors of NSFWQI for each sampling station of Karoon and Dez Rivers have been demonstrated. As shown, the turbidity parameter was omitted due to its low value. Table 5 shows the final index of NSFWQI and its quality meaning for both original and recalculated weight factors. The final index shows the water quality at each. Table 6 shows the EC and Cl^- that were measured in 10 sampling stations near Ahvaz city. As can be seen, some data were omitted because they were not in the Khuzestan Water and Wastewater Company database.

Table 2: Temporary and final weight factors of NSFWQI parameters.

Quality parameter	Power of polluting 1	2	3	4	5	Average	Temporary weight factor	Final weight factor	Original final weight factor
DO	8	5	4	1	–	1.888	0.82	0.13	0.17
BOD_5	10	6	2	–	–	1.556	1.00	0.15	0.11
pH	3	8	5	2	–	2.333	0.67	1.10	0.11
Nitrate	7	4	6	–	1	2.111	0.74	0.11	0.10
Phosphate	3	3	9	2	1	2.722	0.57	0.09	0.10
TS	4	8	2	4	–	2.333	0.67	0.10	0.07
T°	1	1	8	5	3	3.44	0.45	0.07	0.10
Turbidity	4	6	5	3	–	2.389	0.65	0.10	0.08
Fecal coliforms	11	3	3	1	–	1.667	0.93	0.14	0.16
						Sum	6.5		

Table 3: Modified temporary and final weight factors of NSFWQI parameters without turbidity parameter.

Quality parameter	Average	Temporary weight factor	Final weight factor	Original final weight factor
DO	1.4	1.00	0.19	0.17
BOD_5	2.3	0.61	0.11	0.11
pH	2.1	0.67	0.12	0.11
Nitrate	2.4	0.58	0.11	0.10
Phosphate	2.4	0.58	0.11	0.10
TS	3.2	0.44	0.08	0.07
T°	2.4	0.58	0.11	0.10
Fecal coliforms	1.5	0.93	0.17	0.16
	Sum	5.39	1	

Table 4: The sub-index quantities of quality factors of NSFWQI for each sampling station of Karoon and Dez Rivers.

No.	Station	Parameter pH	DO	T°	TS	BOD_5	Nitrate	Phosphate	Fecal coliforms
Dez River									
1	Chamgalak	91	76	90	58	80	92	100	22
2	Dezful Qand Industry	84	88	90	20	76	82	100	22
3	Shirin Water	89	71	90	20	58	75	100	22
4	Mostofi	90	51	90	20	64	69	99	22
5	Dez–Ghir Weir	89	65	90	20	76	84	100	22
Karoon River									
6	Abbaspour Dam	91	73	90	60	80	89	99	22
7	Gatvand Dam	88	80	90	20	92	88	100	22

Continued

Table 4: *Continued*

No.	Station	Parameter							
		pH	DO	T°	TS	BOD_5	Nitrate	Phosphate	Fecal coliforms
9	Shatit–Shooshtar	82	80	90	20	74	92	99	9
10	Gargar–Shooshtar	81	78	90	20	63	85	100	9
11	Shatit–Ghir Weir	87	80	90	20	86	90	100	9
12	Gargar–Ghir Weir	85	82	90	20	76	81	99	9
13	Karoon–Ghir Weir	89	75	90	20	82	83	100	9
14	Ramin	89	77	90	20	86	82	94	9
15	Zargan	88	68	90	20	86	71	100	8
16	New Side	89	79	90	20	74	82	99	8
17	Ahvaz 5th Bridge	90	79	90	20	70	92	98	8
18	Chanibie	88	74	90	20	67	82	98	8
19	Um Al Tamir	89	69	90	20	67	79	100	9
20	Darkhovein	87	78	90	20	82	83	100	9
21	Nahrmard	84	86	90	20	80	79	99	9
22	Khorramshahr Soap Industry	88	57	90	20	69	70	100	9
23	Haffar	86	76	90	20	67	81	99	22
24	Bahmanshir	71	76	90	20	70	89	99	22
25	Choebade	81	76	90	20	68	80	99	22

Table 5: The final index of NSFWQI and its quality meaning for both original and recalculated weight factors.

No.	Station	Quality index			
		Original index	Original index meaning	Recalculated index	Recalculated index meaning
Dez River					
1	Chamgalak	66.38	Medium	66.48	Medium
2	Dezful Qand Industry	60.96	Medium	58.43	Medium
3	Shirin Water	56.64	Medium	53.88	Medium
4	Mostofi	53.29	Medium	51.75	Medium
5	Dez–Ghir Weir	58.10	Medium	56.54	Medium
Karoon River					
6	Abbaspour Dam	65.74	Medium	66.01	Medium
7	Gatvand Dam	61.96	Medium	60.42	Medium
8	Mizan Weir	61.08	Medium	58.68	Medium
9	Shatit–Shooshtar	51.72	Medium	50.32	Bad-Medium
10	Gargar–Shooshtar	50.11	Bad-Medium	48.27	Bad
11	Shatit–Ghir Weir	52.89	Medium	51.86	Medium
12	Gargar–Ghir Weir	51.61	Medium	50.08	Bad-Medium
13	Karoon–Ghir Weir	51.65	Medium	50.57	Bad-Medium
14	Ramin	51.76	Medium	50.77	Bad-Medium

Continued

Table 5: *Continued*

No.	Station	Quality index			
		Original index	Original index meaning	Recalculated index	Recalculated index meaning
15	Zargan	49.04	Bad	48.30	Bad
16	New Side	51.45	Medium	49.00	Bad
17	Ahvaz 5th Bridge	50.77	Bad-Medium	49.28	Bad
18	Chanibie	49.15	Bad	47.63	Bad
19	Um Al Tamir	49.45	Bad	47.49	Bad
20	Darkhovein	51.75	Medium	50.51	Bad-Medium
21	Nahrmard	51.16	Medium	50.63	Bad-Medium
22	Khorramshahr Soap Industry	47.15	Bad	46.17	Bad
23	Haffar	58.58	Medium	56.17	Medium
24	Bahmanshir	59.05	Medium	56.85	Medium
25	Choebade	58.08	Medium	55.72	Medium

Table 6: EC (in µMohs/cm) and Cl^- (in mg/L) quantities in 11 sampling stations.

Stations	Month													
	September		October		November		December		January		February		March	
	EC	Cl^-	EC	Cl^-	EC	Cl^-	EC	Cl^-	EC	Cl^-	EC	Cl^-	EC	Cl^-
1	311	22.68	359	–	395	38.4	525	–	541	–	523	60	487	–
2	–	78.84	1520	–	1032	132.8	970	–	1500	–	1050	110	1270	–
3	1000	111.2	799	–	1080	147.6	1220	–	1440	–	1220	237	1590	–
4	–	118.26	1230	–	1350	259.8	1650	–	2240	–	2460	379	1550	–
5	–	216	1920	–	2040	232.2	2620	–	3120	–	1890	303	1900	–
8	–	115.56	1390	–	1240	231.2	1180	–	1780	–	2120	277	1530	–
13	1590	142.56	1420	–	1340	246	1420	–	2100	–	1750	265	1670	–
14	1410	120.96	1390	–	1100	232.2	1630	–	2120	–	1720	245	1830	–
17	1480	154.44	1630	–	1300	198.7	1300	–	2600	–	2240	390	1410	–
18	1510	154.44	1610	–	1300	227.3	1360	–	2500	–	2240	395	1500	–
19	4610	706	4580	–	1750	314.9	2150	–	2600	–	2200	438	2720	–

4 DISCUSSION

Figures 3 and 4 show the trends in the physical, chemical and biological sub-indices along the length of the Dez and Karoon Rivers, respectively. Only temperature has a significant change between stations 1 and 2 along the Dez River from 60 to 20, pH declined from 90 to 81 in this River and TS is stable(Fig. 3a). Agricultural discharges along the Dez River account for the change (Fig. 2). Quality deterioration problem can be observed in chemical and biological sub-indices along the Dez River (Fig. 3b and c). Only the phosphate sub-index is stable. The DO increased from 73 at the first station to 78 at the fifth station. Figure 4a shows that the pH sub-index has an almost stable trend and only

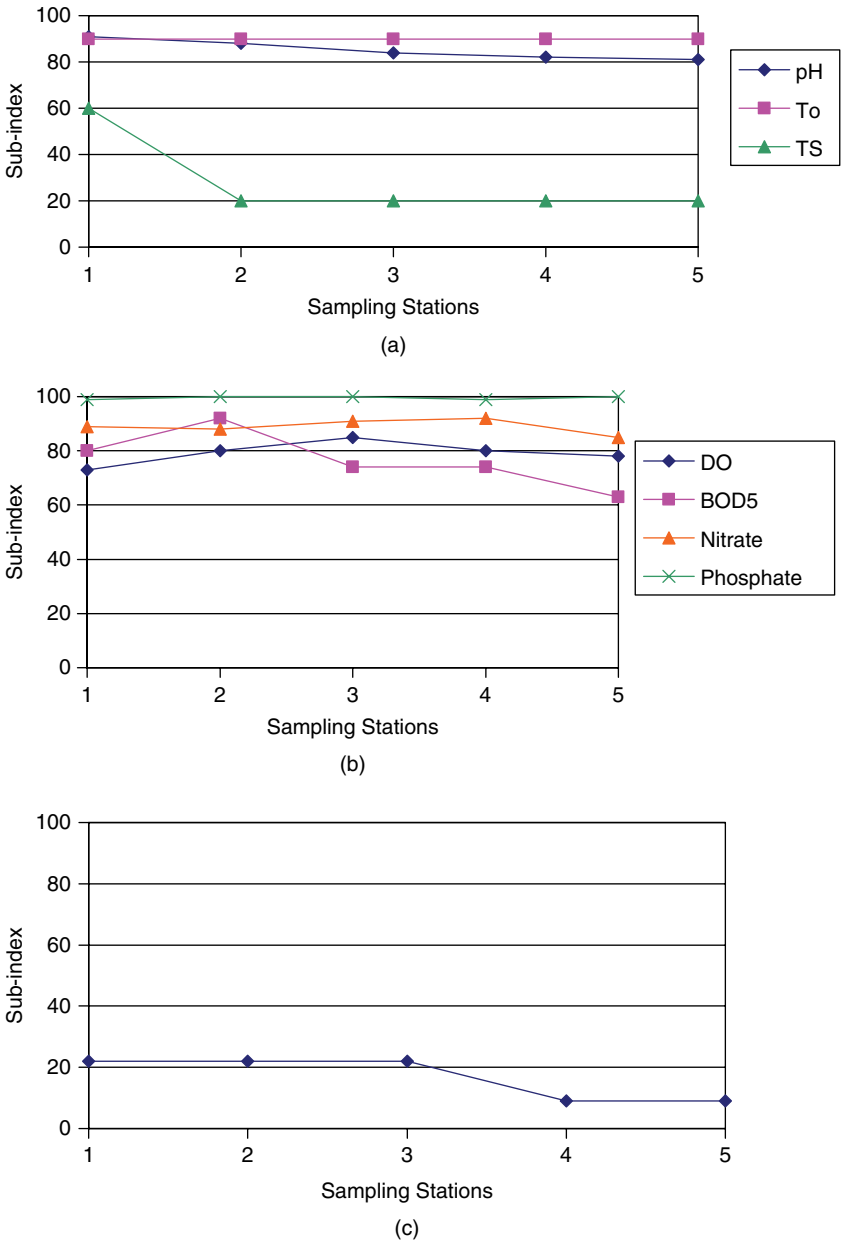
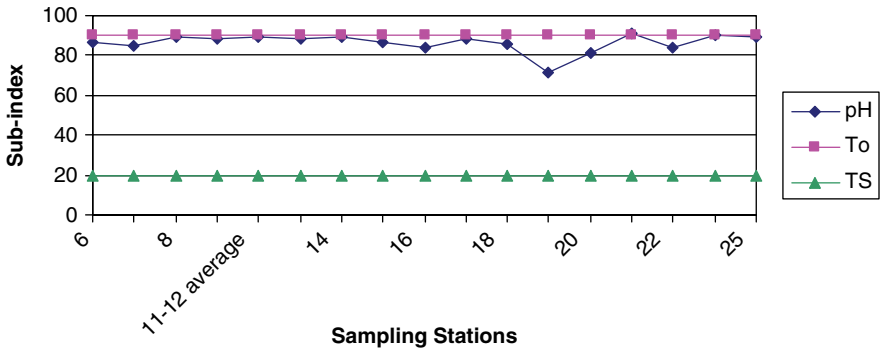
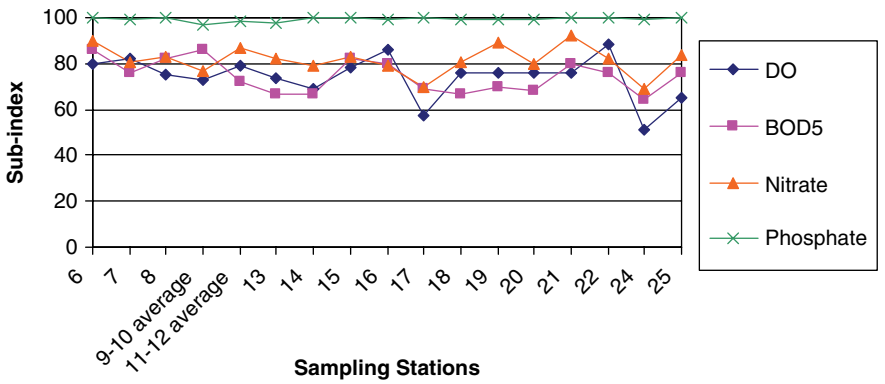


Figure 3: Changes trend of sub-indices in the length of Dez River: (a) physical, (b) chemical, (c) biological.

decreased in station 19 to 71. although it increased to 91 at station 21. Other physical sub-indices are stable along the length of the Karoon River. The average of physical sub-indices of the Karoon River is 86.24 ± 4.70 for pH, 90 ± 0.00 for temperature and 20 ± 0.00 for TS. Chemical sub-indices trends (Fig. 4b) show that only the phosphate sub-index had an almost stable trend with average of



(a)



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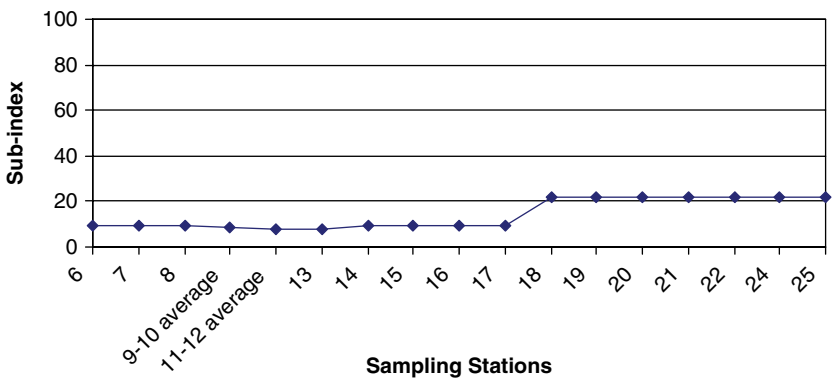
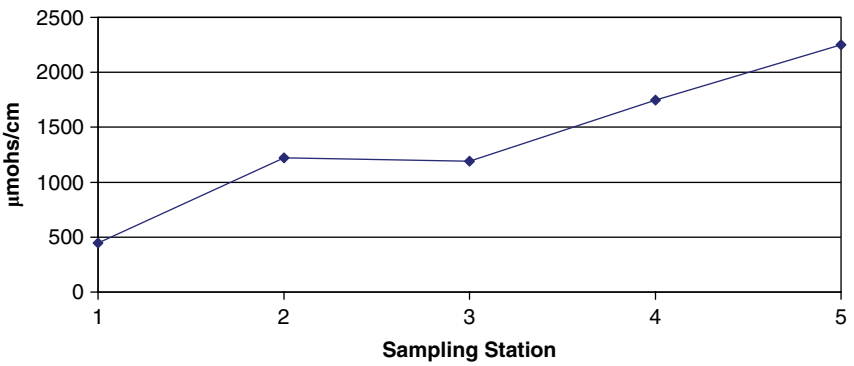


(c)

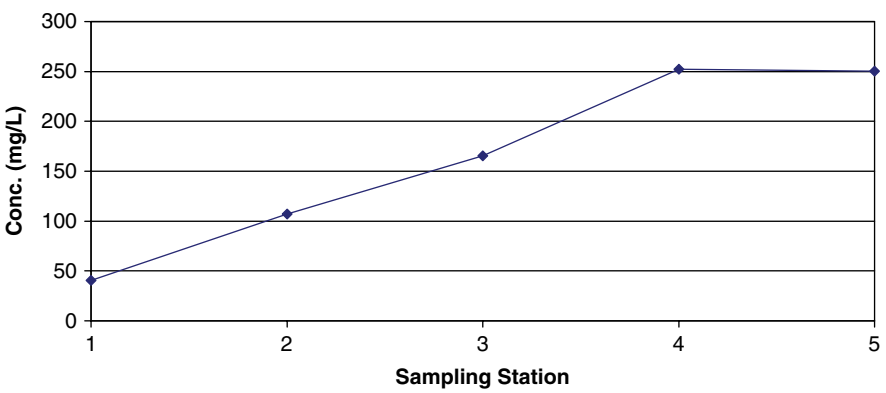
Figure 4: Changes trend of sub-indices in the length of Karoon River: (a) physical, (b) chemical, (c) biological.

99.26 ± 0.87 and DO has the most unstable trend of 74.15 ± 9.43 along the length of the Karoon River. The Nitrate and BOD_5 sub-indices also have stable trends with 81.62 ± 6.17 and 74.59 ± 5.17, respectively. The BOD_5 and DO sub-indices do not have similar trends. Overall, it could be concluded that self-purification in the Karoon River is not coping with wastewater discharge. Figures 5 and 6 demonstrate salinity changes in the Dez and Karoon Rivers, respectively. The water quality deterioration in both Dez and Karoon Rivers is evident in the salinity trend. The Cl^- concentration is more than the standard for domestic and industrial uses, but is suitable for agriculture and irrigation [22].

In general, wastewater discharges from several points (industrial, agricultural, domestic, etc.) in the Karoon River caused water quality decline along the length of the Karoon River. However, the self-purification capacity of the Karoon River resulted in an improvement in the quality of Karoon River towards the bottom of the catchment. In Fig. 7, quality zoning of Dez and Karoon Rivers based on recalculated NSFWQI is demonstrated. The water quality of the Dez River and Karoon branch were in medium condition while the water quality between the stations 10 and 12 was classified as bad to medium and this condition continues to station 14. The water quality of the Karoon River between the stations 14–19 declines. The water quality



(a)



(b)

Figure 5: Salinity changes trend of Dez River: (a) EC, (b) Cl^-.

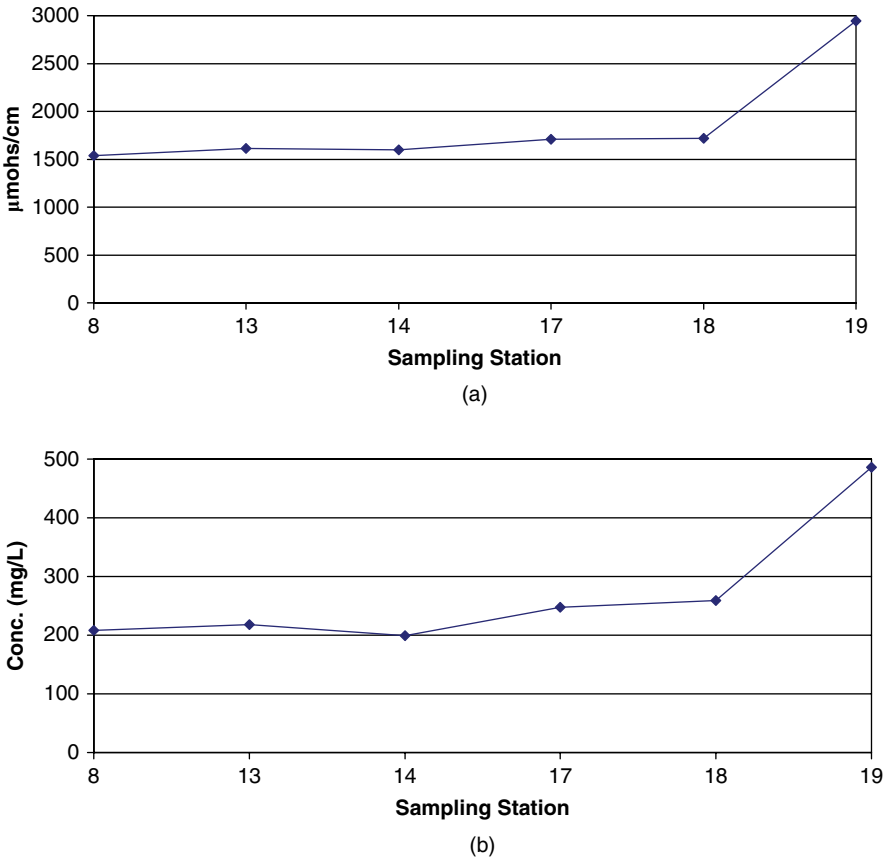


Figure 6: Salinity changes trend of Karoon River: (a) EC, (b) Cl^-.

of the Karoon River improves in the lower section of the river, probably because of inflow from the Arvand River.

In general, the Dez River is suitable for recreational uses, but needs conventional treatment of industrial and domestic uses. However, the Karoon River is not suitable for recreational uses and needs advanced treatment of industrial and domestic uses.

5 CONCLUSION

The National Sanitation Foundation Water Quality Index, which gives a single value to the water quality of a river enabled an evaluation of water quality trends and likely causes of deteriotation in water quality along rivers in the Karoon River catchment. The Karoon River is the longest and one of the most important rivers in Iran and is an important source of water for agricultural, industrial, domestic and recreational uses. Thus, having water quality indices and zoning plan for this river aid the experts to better manage how to use the water for suitable uses based on its quality and also discharge wastewaters to this river. Unfortunately, this study shows that the water quality of the Dez and Karoon Rivers is poor, probably due to wastewater discharges. An integrated program to manage water quality along the Dez and Karoon Rivers is required if the resource is not to be further degraded.

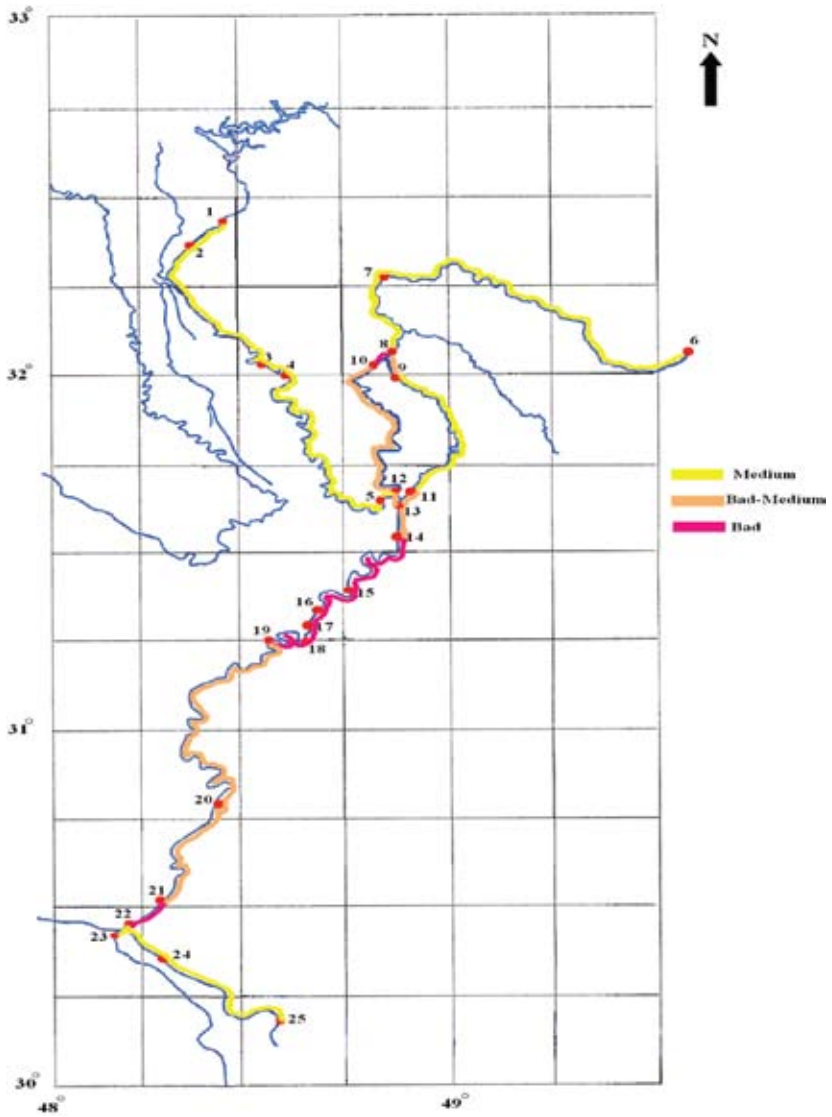


Figure 7: Quality zoning of Dez and Karoon Rivers based on recalculated NSFWQI.

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