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Survey on monthly variations of water quality in the Tajan River (Sari, Iran)

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The aims of the study were to evaluate water quality of Tajan River in Sari in terms of chemical pollution and the impact of pollutant sources near the river by considering the climate, hydrological and hydraulic condition on it. In this study, 10 critical points of river were selected as sampling stations from dam to sea. Sampling was randomly done monthly from Apr 2009 to Mar 2010. Samples were analyzed in terms of chemical parameters after transferring to the laboratory according to standard methods. The results showed that the pH and temperature were within acceptable ranges of 6.5 to 8.5 and < 20°C, respectively. The minimum dissolved oxygen (DO) concentrations were above 6 mg/L along the river. Fish can survive because DO content was high. The maximum levels of biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphate (PO_4) and nitrate (NO_3) were at or below 30, 17, 0.5 and 0.7 mg/L, respectively. In general, the results showed that the physical and chemical qualities of water from Tajan River were within the acceptable limits for agricultural consumptions. In addition, Tajan River water can be classified in Class II.

Key words: Water quality, Tajan River, river pollution, water pollution.

INTRODUCTION

Water quality plays important role on the health of human, animals and plants. The quality of surface water within a region is governed by both natural and anthropogenic effects (Pejman et al., 2009). A variety of methods are being used to display the information which is concealed in the quality variables observed in a water quality monitoring network. Human activities are a major factor to determine the quality of the surface and ground water through atmospheric pollution, effluent discharges, use of agricultural chemicals, eroded soils and land use.

Discharging of degradable wastewater in flowing waters lead to a decrease of dissolved oxygen concentrations due to metabolism of pollutants by microorganisms, chemical oxidations of reduced pollutants, and respiration of plants, algae and phytoplankton (Kannel et al., 2007).

A good river health meets the threshold levels of key parameters: dissolved oxygen (DO), biochemical oxygen demand (BOD), total nitrogen (TN), total phosphorus (TP), temperature and pH (Pejman et al., 2009). DO concentration is vital for the survival of fisheries. It is the most important parameter for protecting fish. Fish cannot survive when DO content is less than 3 mg/L (Kannel et al., 2007).

In order to sustain the use of water resources for

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Table 1. Water quality classification based on IEPA (Hassani et al., 2011).

Parameter	Class				
	I	II	III	IV	V
pH	6.5-7.5	6.0-6.5 and 7.5-8.0	5.0-6.0 and 8.0-9.0	4.5-5.0 and 9.0-9.5	<4.5 and >9.5
Total dissolved solids (mg/L)	500	1500	2100	3000	>3000
Turbidity (NTU)	5	10	20	250	>250
Dissolved oxygen saturation (%)	88-112	75-125	50-150	20-200	<20 and >200
Nitrate (mg/L)	11	22	45	90	>200

drinking, agricultural, industrial and tourism, pollutant must enter rivers according to self-purification ability. The self-purification is the natural processes that destroy the pollutants entering the water. If the discharged pollutants to the water were more than purification potential, water cannot purify itself. Water's self-purifying ability has its limits. Iranian Ministry of Energy (IMOE) classified surface water as Oilgosaprobic, β mesosaprobic, α mesosaproblic and Polysaprobic systems based on biological index (IMOE and IMPORG, 2010a). Also, in other Iranian guideline for water quality monitoring of dams reservoirs, water is classified based on relationships between phosphorus (mg/l), minimum oxygen concentration (sat %), and Trophic Class. There are five classes in this classification, named as Ulrtaoligotrophic, Oligotrophic, Mesotrophic, Eutrophic, Hypereutrophic (IMOE and IMPORG, 2010b). Furthermore, according to Iranian Environment Protection Agency (IEPA), water quality can be classified into five classes as Table 1 shows (Babaei Semiromii et al., 2011).

Many rivers or streams in the developing countries are heavily polluted due to anthropogenic activities, such as industrial and sewage discharges (Jonnalagadda and Mhere, 2001). In this case, there are many studies (Bordalo et al., 2001; Jonnalagadda and Mhere, 2001; Ehiagbonare et al., 2009; Hacioglu and Dulger, 2009; Osibanjo et al., 2011). There are many rivers and streams in Iran. Literature shows that some rivers in Iran have been studied (Karamouz et al., 2006; Marofi and Maryanaji, 2007; Pejman et al., 2009). These rivers are the main sources of water supply in industry, agriculture and urban regions. Therefore, the quality control is very important. Tajan River in the city county in northern Iran, is one of the major rivers, in which, unfortunately, various kinds of waste and wastewaters are discharged. Tajen River runs to the plains carrying the waters from various tributaries in the mountains. Finally, Tajan River joins the Caspian Sea. The Tajan River water is extensively used for irrigation. A systematic study on the river water quality is of great necessity and significance. Therefore, the aims of the study were to evaluate water quality of Tajan River in Sari in terms of chemical pollution and the impact of pollutant sources near the river by considering the climate, hydrological and hydraulic condition on it.

MATERIALS AND METHODS

Study area and sampling sites

Figure 1, the map of the river area, illustrates the study area and locations of the sampling sites. As shown in Figure 1, ten sampling sites were chosen for the study. Sampling stations named 1 to 10 from dam to sea were as follows: Number 1 was near Mazandaran Wood and Paper industry (upstream, 200 m to wastewater discharge point of Mazandaran Wood and Paper industry) representing the background values, that is with little interference from anthropogenic activities. Number 2 was in the downstream of wastewater discharge point of Wood and Paper factory (800 m after discharge of effluent of Mazandaran Wood and Paper industry). Number 3 was before the entry of the river the city of Sari (village Baladeza). Number 4 was before Tajan Bridge and during passing through the city (before entering the sewage of paksar pasteurized Milk Company). Number 5 was 500 to 600 m after entering the sewage of pasteurized milk company (Paksar). Number 6 was the end of the city. Number 7 was before the point of discharge of sewage antibiotic plant. Number 8 was after discharging the effluent antibiotics. Number 9 was under Bridge Village (10 km from the sea). sNumber 10 was sited 500 m upstream of the Caspian Sea (before entering the sea).

Sample collection and analysis

In this study, 10 critical points of river were selected as sampling stations in river from dam to sea. Water samples were collected from the 10 stations (from depths of 20 and 80 cm water level) for a year from Tajen River. The collected samples were kept in 2 L polyethylene plastic bottles cleaned with metal free soap, rinsed many times with distilled water and finally soaked in 10% nitric acid for 24 h, and finally rinsed with ultrapure water. Sampling was done from April 2009 to March 2010.

All water samples were stored in insulated cooler containing ice and delivered to the laboratory the same day and all samples were kept at 4°C until processing and analysis time. Samples were analyzed viewpoint of chemical parameters after being transferred to the laboratory according to the standard methods (APHA, 2005). The number of sample was calculated according to this formula:

$$d = 0.3, \delta = 1.7 \rightarrow n = \frac{z^2_{1-\frac{\alpha}{2}} \times \delta^2}{d^2} \cong 120$$

The selected water quality parameters consisted of dissolved oxygen (DO), turbidity, electrical conductivity (EC), total dissolved solids (TDS), pH, water temperature (T), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate (NO_3), and phosphate (PO_4). Analysis was done according to the standard methods for water and wastewater analysis (APHA, 2005). In case

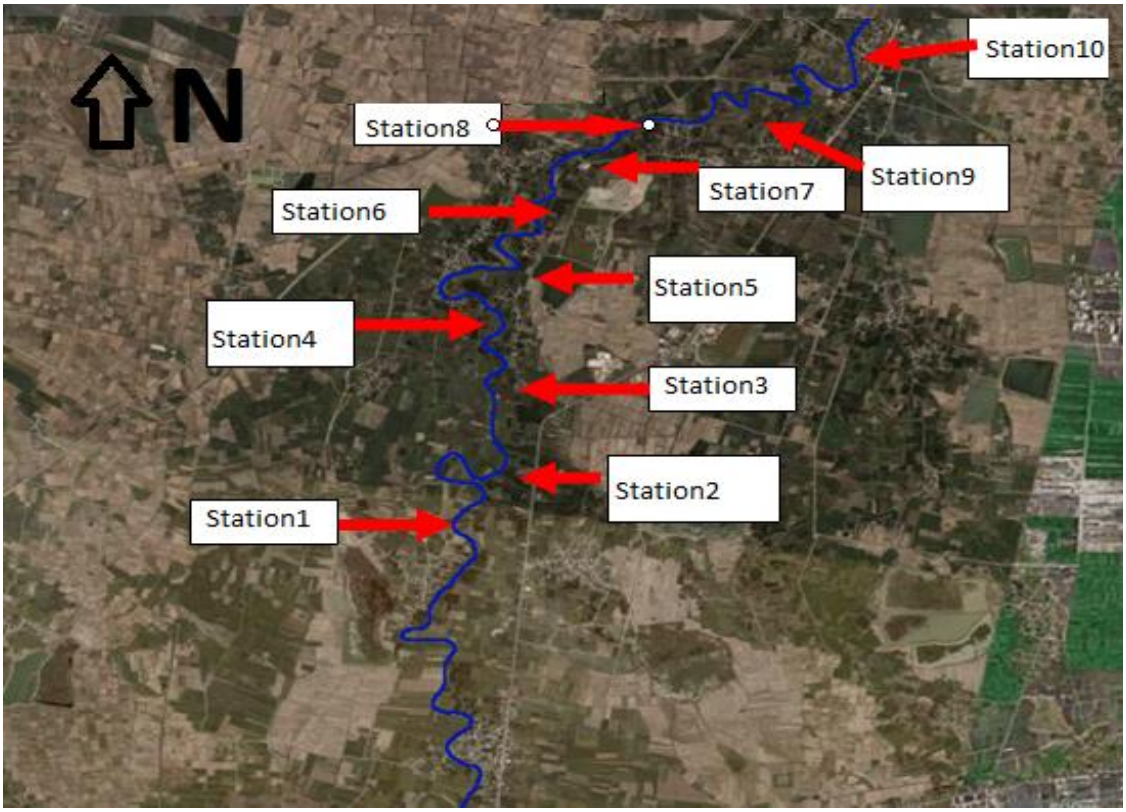

Figure 1. Map of the study area and surface water quality sampling stations in Tajan River Basin.

Table 2. Water quality parameters, abbreviations, units, analytical methods and instruments used in this study.

Parameter	Abbreviation	Unit	Analytical method	Method number	Analytical instrument
pH	pH		pH-meter	4500-A	Aqualytic, pH200
Temperature	T	°C	Thermometer	-	Mercury Thermometer
Electrical conductivity	EC	µs /cm	Electrical conductivity	2520-B	Aqualytic, CON200
Total dissolved solids	TDS	mg/L	Gravimetric	2540-B	-
Turbidity	Turbidity	NTU	Nephelometric method	2130-A	HACH, 2100A
Dissolved oxygen	DO	mg/L	Winkler azide method	4500-OC	-
Chemical oxygen demand	COD	mg/L	Open Reflux	5220_D	-
Biochemical oxygen demand	BOD	mg/L	Winkler azide method	5210-B	-
Nitrate	NO3	mg/L	Brucine sulfate	352-1	Jenway spectrophotometric
Phosphate	PO4	mg/L	Stannous chloride	4500-D	Jenway spectrophotometric

of nitrate, it was analyzed according to ASTM (2008). Temperature and pH values of water samples were measured in the field using a thermometer and a pre-calibrated portable pH meter, respectively. The water quality parameters, their units and methods of analysis are summarized in Table 2.

RESULTS AND DISCUSSION

The ten indicator parameters used in the water quality assessment were as follows: pH, BOD, COD, nitrate, phosphate, temperature, TDS, DO, turbidity and EC. Table 3 summarizes the typical results obtained at different sampling points during a year. The average range of pH was from 7.8 ± 0.2 to 8.22 ± 0.1. High pH value indicates that a large buffering capacity exists within the sites (Marofi and Maryanaji, 2007). As the permissible range of pH is 6 to 9 for bathing water quality and 6.5 to 8.5 for the fisheries (Kannel et al., 2007), Tajan river can allow fishery and recreational activities. According to the TDS, EC and pH, a strong

Table 3. The mean results of water quality parameters from 10 sampling stations of Tajan River from April 2009 to March 2010.

Station number	Number of Sample	pH	T(◦C)	EC(µs/cm)	TDS (mg/L)	Turbidity (NTU)	DO (mg/L)	COD (mg/L)	BOD (mg/L)	NO_3 (mg/L)	PO_4 (mg/L)
1	12	8.22±0.1	15.6±6	464±148	278±34	176±80	8.6±0.6	9.4±3.9	5.3±2.9	0.56±0.29	0.14±0.12
2	12	8±0.2	16.3±5.5	549±188	383±90	801±80	8.1±0.8	20.3±5	11±3.9	0.69±0.3	0.23±0.24
3	12	8.1±0.2	16.6±5.7	508±170	313±56	196±57	8.2±0.7	15.3±5.3	8.4±3.2	0.62±0.27	0.15±0.12
4	12	8.1±0.2	17±5.8	518±175	315±52	158±40	8.3±0.6	13.4±4.7	7.5±2.9	0.5±0.21	0.14±0.09
5	12	8.2±0.1	17.5±6	509±168	313±48	142±46	8.3±0.7	14.8±4.8	8.7±3.4	0.59±0.24	0.16±0.1
6	12	8.1±0.2	17.7±6	517±173	316±43	133±47	8.09±0.6	14.5±4.7	9.2±3.5	0.67±0.26	0.17±0.11
7	12	8±0.2	17.9±5.8	529±172	322±38	130±54	8.2±0.5	14.2±5.5	8.1±3.3	0.62±0.20	0.21±0.18
8	12	8±0.2	18.2±5.7	540±169	333±26	127±67	8.1±0.4	16.4±5.5	9.5±4.2	0.72±0.31	0.13±0.08
9	12	8±0.1	18.4±5.7	558±174	345±32	116±59	7.93±0.5	13.3±4.8	7.2±3.2	0.65±0.26	0.13±0.11
10	12	7.8±0.2	18.9±5.8	1193±536	750±173	65±52	6.8±0.5	12±4.1	6.9±2.9	0.53±0.30	0.07±0.06

spatial variability was identified on the water chemistry of the region. EC qualitatively reflects the status of inorganic pollution and is a measure of TDS and ionized species in the water (Jonnalagadda and Mhere, 2001). The average EC ranged from 464 ± 148 to 1193 ± 536 µs/cm. The sampling site Number 1 recorded the lowest conductance values throughout the study period. Stations 2 to 9 recorded a slight increase in values (Figure 2). Conductance values increased as the river descended through the plains. The highest observed was recorded at the last station due to the effects of the sea. It means that the water of Tajan River is non-saline for agricultural irrigation, except near the sea; in station 10 which is slightly saline. The variations of TDS values are similar to the conductance variation as other studies showed that the TDS values correlated well with the conductance values (Marofi and Maryanaji, 2007). In agreement with the high conductance values, TDS levels were high at the same sampling points. Based on comparison of data with IEPA guideline (Table 1), it is seen that the water of Tajan River belonged to Class I from TDS point of view.

Table 4 shows the classification of agricultural water quality from salinity point of view (IMOE and IMPORG, 2010C). Furthermore, the closer it was to the sea, the more the concentration increased. The average TDS variations were similar to EC in different sites. The results of the nitrate in Tajan River was excellent or class I according to IEPA rating scale that designates 0 to 11 mg/L nitrate as very low (rated as excellent). There are other reports with the same results of water quality (Marofi and Maryanaji, 2007; Babaei Semiromi et al., 2011). In general, the results show that the physical and chemical quality of water from Tajan River was acceptable limits for agricultural consumption in all normal conditions except near the sea.

The trend of concentration variations of temperature, BOD, DO and COD in Tajan River at 10 sampling stations is shown in Figure 3. BOD and COD values indicate the extent of organic pollution in the aquatic systems, which adversely affect the water quality. As Figure 3 shows trend BOD was similar to that of COD. In all the samples, BOD values were low and between 3 and 17 mg/l. Relatively, high values were observed at station 2, which is likely due to the effluents from the Mazandaran wood and paper industry.

Oxygen saturation concentration in the water depends on temperature. The temperature was 15 to 20°C, so the oxygen saturation was 9.2 to 10.2 mg/l (Karamouz and Kerachian, 2003) while the actual concentration of oxygen ranged from 6 to 8.6 mg/l. This means that Oxygen saturation concentration was 65 to 93%. DO concentration is vital for the survival of fisheries. It is a barometer of the ecological health of a stream and is the most important parameter for protecting fish (Kannel et al., 2007). Based on the results of that compared the data with IEPA (Table 1), it is seen that the water of Tajan River belonged to Class II; for parameter of DO. In addition, in this study, DO concentration was over 6 mg/l in all points, therefore, it is suitable for fisheries.

The average of temperature was 15 to 20°C in this study. It means that Tajan River is suitable for cold and warm fisheries. The limit of temperature

Table 4. Classification of water salinity for agricultural use (IMOE and IMPORG, 2010C).

Parameter	Non-saline	Slightly salin	Brackish	Saline	Very saline	Hyper saline
TDS (mg/L	500**>**	500-1500	1500-5000	5000-8000	8000-13000	>13000
EC (µs/cm)	700**>**	700-2500	2500-8000	8000-12000	12000-20000	>20000

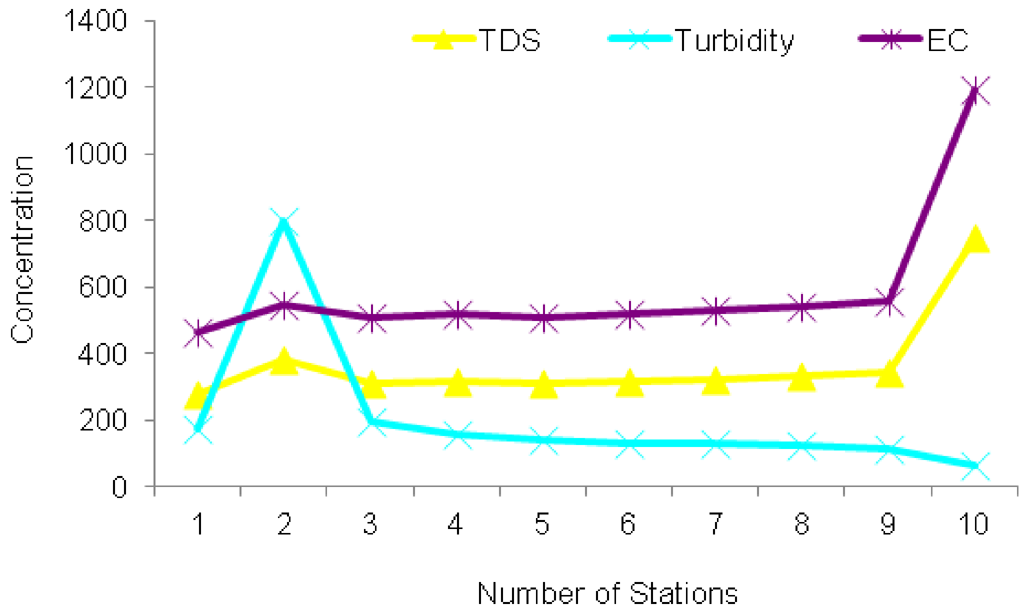

Figure 2. The trend of concentration variations of turbidity (NTU), electrical conductivity (µs/cm) and total dissolved solids (mg /l) in Tajan River at 10 sampling stations.

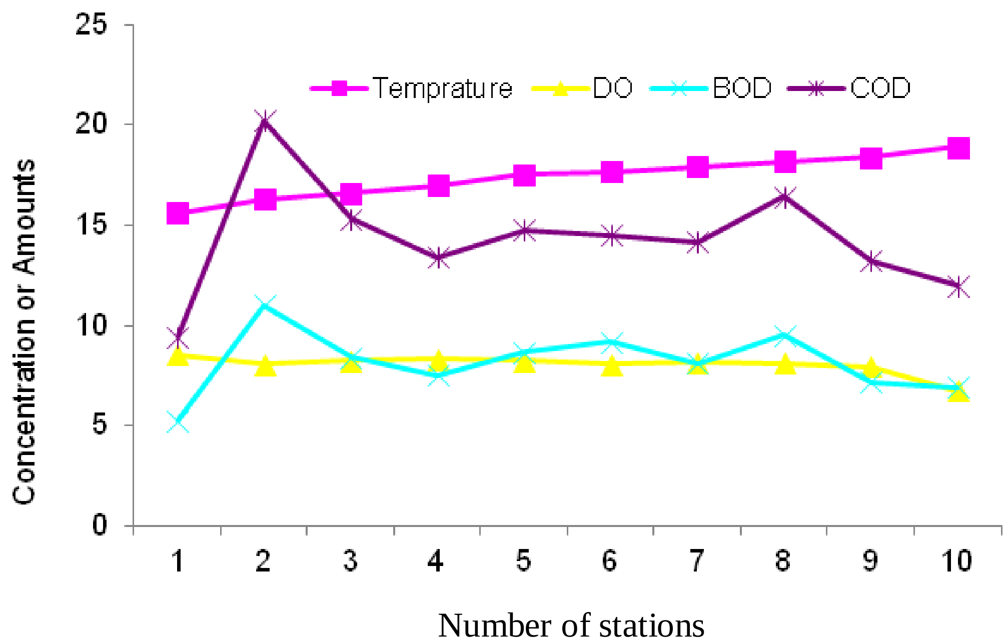

Figure 3. The trend of concentration variations of temperature (°C), BOD (mg/l), DO (mg/l) and COD (mg/l) in Tajan River at 10 sampling stations.

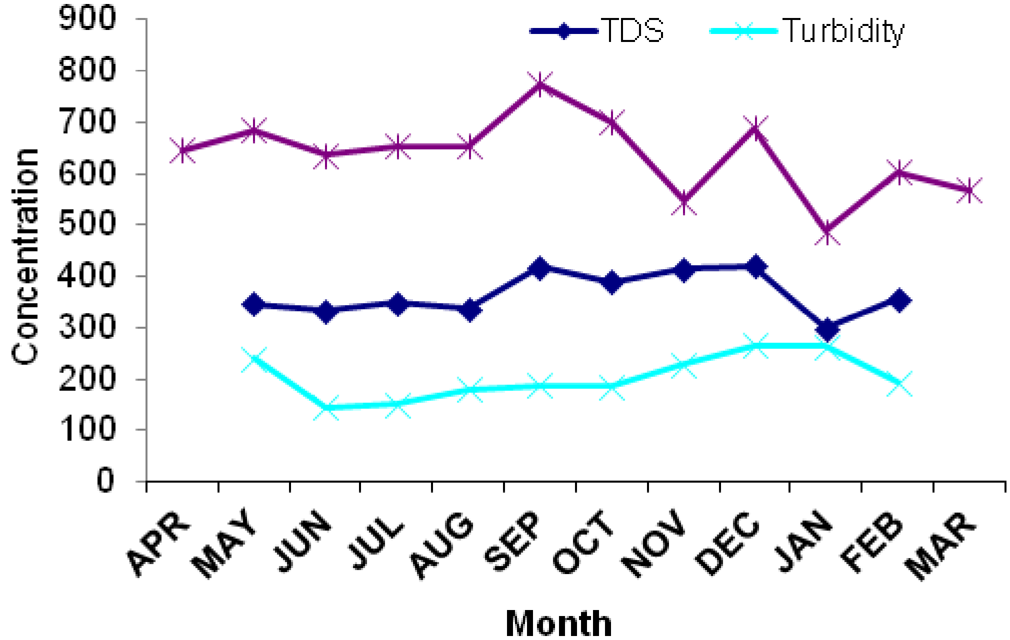

Figure 4. The trend of mean concentration variations of turbidity (NTU), electrical conductivity (μs/cm) and total dissolved solids (mg/l) in Tajan River in different months.

was 28.3 C for warm-water fisheries, 20°C for cold-water fisheries (Kannel et al., 2007).

The permissible limit of TN stated by IEPA is 11 mg/L for rivers of class I (Table 2). It means that Tajan River has low nitrate. TP limit set by USEPA is 0.1 mg/L to control eutrophication (Kannel et al., 2007). Although, in this study, ortho-phosphorus was measured, its concentration was more than 0.1 mg/l, therefore; Tajan River has the potential of eutrophication and algal especially in warm seasons.

The monthly variations of physiochemical properties from the ten sampling sites along Tajan River form April 2009 to March 2010 are given in Figures 4 to 6. The figures show that the mentioned parameters had similar trend. The average temperature increased from July to September as climate got warmer. The temperature was observed to be highest in summer. It increased as ambient temperature increased. The temperature of water was lowest in winter months. Temperature of water may not be as important because of the wide range of temperature tolerance in aquatic life, but in polluted water, temperature can have profound effects on DO and BOD (Hacioglu and Dulger, 2009). The inverse relationship between temperature and dissolved oxygen is a natural process because warmer water gets more easily saturated with oxygen and it can hold less dissolved oxygen (Hacioglu and Dulger, 2009; Pejman et al., 2009). In the case of BOD and COD, the average concentration is higher in summer months in contrast to less level in autumn and winter months. Other researchers reported the same results (Pejman et al., 2009). The average concentration of DO was a little higher in winter and autumn months compared to summer and spring months. In fact, seasonal variations are highly effective in concentration of DO and this amount plays a tremendous role in water quality of rivers. It may be justified by relatively more agricultural, industrial, recreational and fish farming activities in summer and spring.

The seasonal variation of EC show that during the observation period, EC increased slowly in summer months. It could be influenced by the agricultural activity and the decrease of water flow. According to Figure 6, these are not clearly the trend in phosphate and nitrate levels with an increase of distance from dam to sea.

Conclusion

The assessment of the quality of Tajan River water revealed that rivers were affected by industrial discharges and agricultural activities. Generally, the results show that the physical and chemical quality of water from Tajan River was within acceptable limits for agricultural consumptions. The pH and temperature were within acceptable ranges of 6.5 to 8.5 and < 20°C, respectively. The minimum DO concentrations were above 6 mg/L along the river. Fish can survive because DO content level is high. The maximum levels of BOD, COD, PO_4 and NO_3 were at or below 30, 17, 0.5 and 0.7 mg/L,

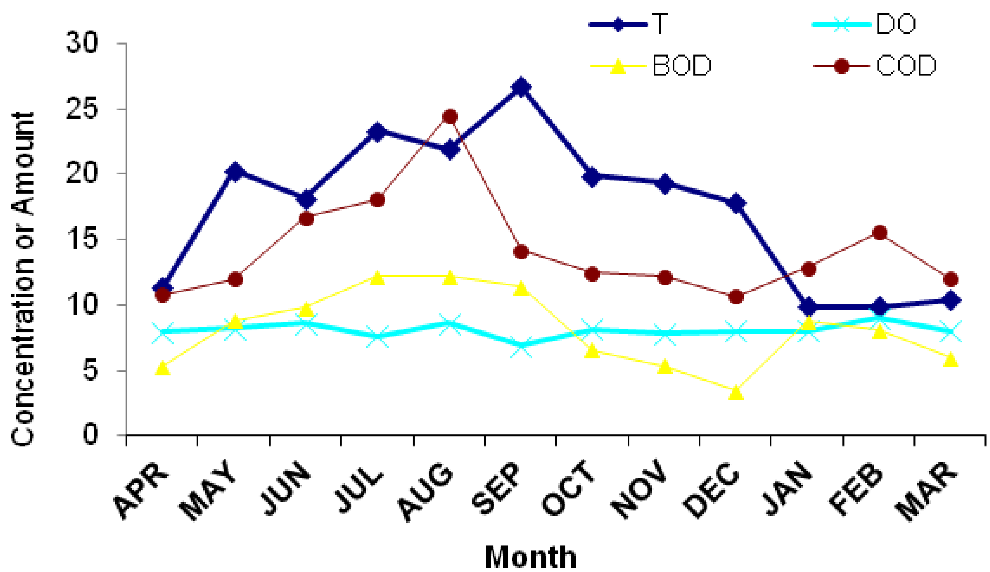

Figure 5. The trend of mean concentration variations of Temperature (oC), BOD (mg/l), DO (mg/l) and COD (mg /l) in Tajan River in different stations.

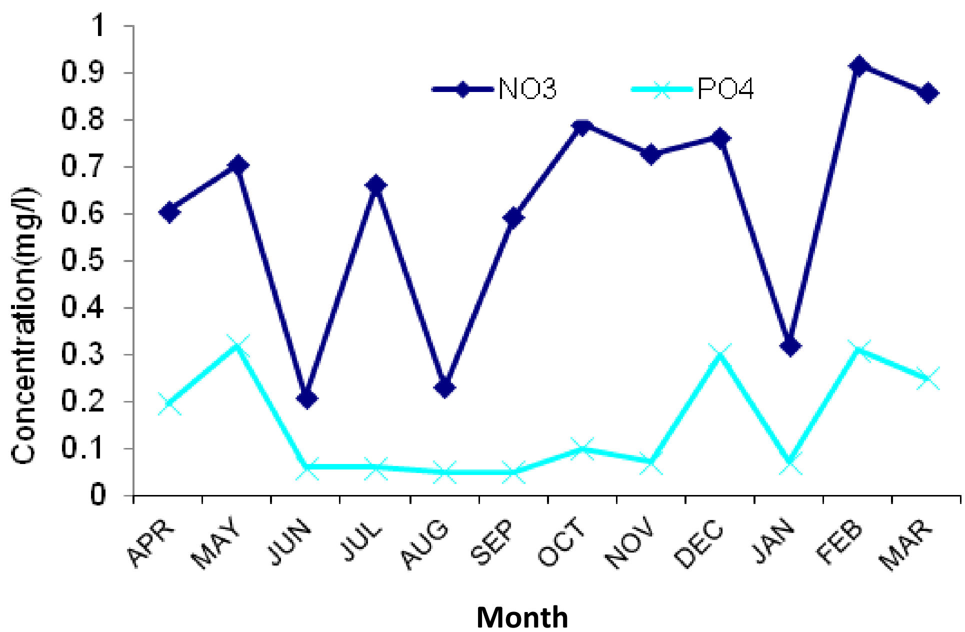

Figure 6. The trend of concentration variations of phosphate and Nitrate in Tajan River at 10 sampling stations.

respectively. Due to high volume of water in Tajan River, the extent of the pollution in the water may not appear severe. Considering that the river is a source of agricultural water, the pollution potential gains significance. These studies on Tajan and on the other rivers have led to the structuring of a permanent commission to monitor the water quality in some major rivers in Iran.

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