J. Mater. Environ. Sci. 6 (2) (2015) 322-332 *Hamedi et al.*
ISSN : 2028-2508
CODEN: JMESCN

Survey of qualitative conditions and seasonal variation of the urban watercourses pollutants

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Abstract
This paper present the finding of a study which has surveyed the effects of urban pollutants upon the water quality of a big urban watercourse in southeast of Tehran (Sorkhe-Hessar Watercourse). Three sampling stations have been selected. Measurement of the physico-chemical and biological parameters has been taken in the samples from the watercourse, in four varied seasons. Regression results showed the procedural changes of the parameters of nitrates, phosphate, turbidity and TSS were on the increase during the varied seasons; whereas, with the passage of time, the parameters of BOD_5, COD, TDS and EC showed a decremented procedure. Results that obtained from the computed Iran Water Quality Index (IRWQI), it was equivalent to 15-29.9, demonstrated the poor qualitative conditions for the watercourse. The watercourse quality analysis indicated the pollutants load during the wet seasons was higher than the dry seasons due to the high volume of runoff.

Keywords: Water pollution; Urban watercourse; Iran Water Quality Index (IRWQI); Sorkhe-Hessar Watercourse.

1. Introduction
The quality changes of surface waters are intensely under the influence of natural processes such as, the amount of precipitation, weathering processes and human activities like urban, agricultural and industrial [1,2]. In recent years, urban development, population increasing and then an increment in the activities of human, has led to the occurrence of problems and difficulties in the aquatic environment in urban areas [3,4,5].Urban waters have also been associated with water quality problems due to discharging of municipal and industrial waste into the water bodies [6].
One of these surface watersare watercourses and urban canals. These were constructed with the objective to collect and conduct the surface runoffin the past. Though, today, they have been turned into locations for the deposition of wastes, domestic and industrial sewage discharge [7-9]. On the other hand, transportation various ions from the atmosphere, natural surfaces or those constructed surfaces by runoff in urban areas and their discharge into these water bodies with a high concentration has caused the pollution of these locations. As the exploitation of watercourses by human is increased, implementing a sustainable management would be appropriate not only to achieve good ecological conditions of water bodies but to require watercourses to be healthy for human use as well [10].Though, appropriate management of wastes and the control of human activities can minimize the impact of runoff, resulting in a minimal pollution of these watercourses [11]. Suitable management of surface waters in urban areas requires detailed awareness in the case of water quality and likewise, an investigation of various resources that affect the water quality. The quality of water is estimated by analyzing the physical, chemical and biological parameters [12,13].
One of the simple analytical methods for assessment of quality of water resources is to study the water quality index which is considered as a strong management tool in decision-making [14-16]. For this purpose, water quality data for a few key parameters are put into a mathematical formula which indicates in one single figure the level of water pollution. This figure denotes a relative scale of water quality ranging from "extremely poor" to "extremely good".
The Sorkhe-Hessar watercourse which is of a length of 7,800 meters is located in the southeast of Tehran; and is the only river of Tehran, which takes its source from the mountains of slight altitude, to the east of Tehran. This watercourse carries a large volume of runoff due to the topography of the city and also the adjoining of other canals of the city to it. This is in a condition where, when the mentioned watercourse during its passing from Zone 15 (study area) of Tehran city, is intensely endangered of pollution arising from the discharge of domestic

and industrial wastewaters and runoff due to precipitation. A point worthy of attention, in particular with the Sorkhe-Hessar watercourse is that, this watercourse eventually enters the agricultural lands to the south of Tehran and its water is utilized to irrigate these lands. As a result, the consumption of the agricultural products of this region by the people of Tehran has led to the occurrence of a large number of diseases. Hence, in the present research, by analyzing the physico-chemical and biological parameters and computing the Iran Water Quality Index, a survey of the qualitative conditions of this watercourse and the seasonal variations has been performed. Due to the entering high volume of runoff into the watercourse, are expected the watercourse quality would be worse in wet seasons and also the stations that have been located in the densest populated area would be the most polluted.

2. Materials and Methods

2.1. Study Area and Sampling Stations

The Zone 15 is located to the extreme southeast of the Tehran city; and about eight percent of the population of Tehran is allocated in this area (Fig. 1). The mean annual precipitation is approximately 234 mm. With due attention to the topography of the Tehran- 40percent slope in northern foot-hills and 0.5percent slope in southern areas- the entire precipitation atmospherically of the basin is a river system running from north to south; and after entering the slighter altitude regions within the city, it continues on its course in two directions generally, these being, southeast and southwest. Due to the construction of concrete canals and watercourses, runoff rapidly flow towards the south and concentrate there [17].

After regional studies and surveys which took place, three sampling stations according to (Fig. 1) were selected. Selection of one station at the entrance of the watercourse to the study area and the other station at the point where the watercourse exited the region and before it entered croplands in the downstream was considered essential. Similarly, another station was chosen at the mid-course of the watercourse, in a residential area, having the densest population. Specifications and locations of each one of the stations have been rendered in Table (1).

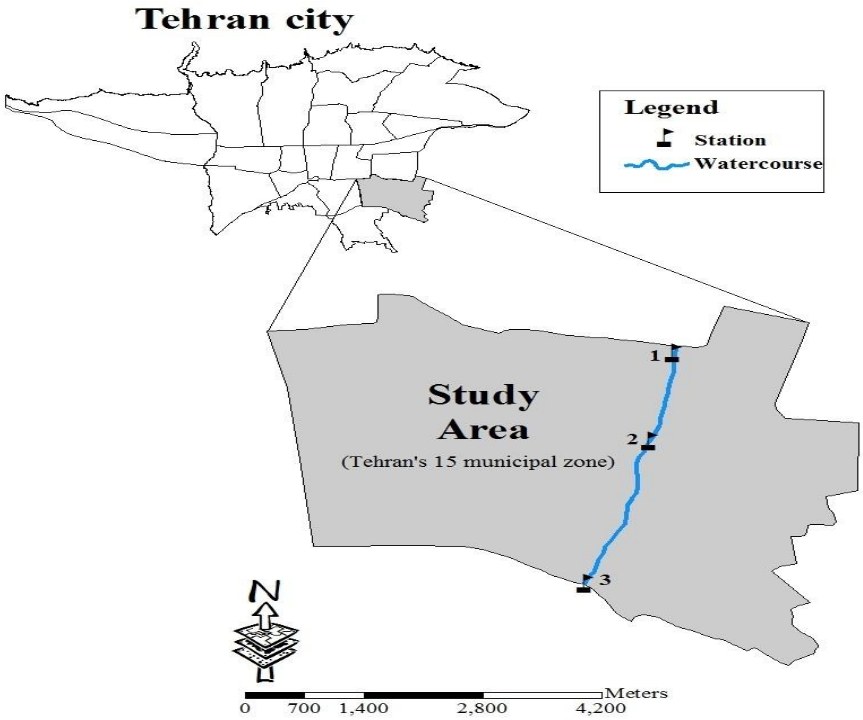

Figure 1: Location of sampling stations along the Sorkhe-Hessar Watercourse

2.2. Sampling and Tests

Sampling with three repetitions at each station was carried out in the varied mid-seasons from the summer of 2011 to spring 2012. Sampling was performed manually from the top layer of the watercourse, close tocenter,where the water was a complete mixture [18]. The samples were put into two-liter polyethylene containers and one-liter bottles (according to type of parameter). The sampling procedures such as type of container for sampling, volume required for the samples, conditions and period as to their maintenance, followed the guidelines and parameters as suggested by Standard Methods – Edition 19 [19]. Parameters that were surveyed in this research, their methods of measuring and the relative instruments are given in Table (2).

Table 1: Details and location of sampling stations along the Sorkhe-Hessar Watercourse

Station No.	Details		Location
	Longitude E	Latitude N	
1	51 29 04	35 39 23	At the entrance of the watercourse to the study area
2	51 28 53	35 38 32	Mid-course of the watercourse, The most densely populated residential area
3	51 28 19	35 37 6	End of the study area, before the watercourse entered croplands

Table 2: Parameters, Analysis Methods and Instrument [19]

Parameter	Analysis Method	Instrument
pH	-	pH Meter
Electrical Conductivity (EC)	-	HQ40D EC Meter
Turbidity	-	2100 Q Turbidity Meter
Biological Oxygen Demand (BOD)	5210 B. 5-Day BOD Test	-
Chemical Oxygen Demand (COD)	5220 D. Closed Reflux, Colorimetric Method	DR 2800 Spectrophotometer UV-visible
Nitrate	4500-$NO3^-$ E. Cadmium Reduction Method	DR 2800 Spectrophotometer UV-visible
Phosphate	4500-P E. Ascorbic Acid Method	DR 2800 Spectrophotometer UV-visible
Ammonia	4500-NH_3 B and C. (Method 8038 Nessler)	DR 2800 Spectrophotometer UV-visible
Total Suspended Solids (TSS)	2540 D. Dried at 103-105°C	BM 120 Oven, Desiccator
Total Dissolved Solids (TDS)	2540 C. Dried at 180°C	BM 120 Oven, Desiccator
Feacal Coliform	9221 E	-
Total Coliform	9221 B	-

Table 3: Water quality index parameters for Iran and their weights

Parameters	Weight	Unit
Feacal coliform	0.140	MPN/100ml
BOD_5	0.117	mg/l
Nitrates	0.108	mg/l
DO	0.097	Saturated percentage
EC	0.096	Microseisms/cm
COD	0.093	mg/l
Ammonium	0.090	Total ammonium
Phosphates	0.087	mg/l
Turbidity	0.062	NTU
Total hardness	0.059	Calcium Carbonate mg/l
pH	0.051	Standard Unit

2.3. Iran Water Quality Index (IRWQI)

In order to monitor the overall conditions of water quality along the watercourses, the IRWQI was utilized. The calculations of this index are as follows:

(1) Selection of water quality parameters and determining their weight based on Table 3,
(2) Obtaining the index value for each parameter by utilizing the classified curves,
(3) Calculating the index value by utilizing the following formula:

$$\mathbf{IRWQI_{SC}} = \left[\prod_{i=1}^{n} I_i^{w_i}\right]^{\frac{1}{\gamma}}$$

in which

$$\gamma = \sum_{i=1}^{n} w_i$$

w_i= weight of each parameter,
n= the number of parameters and
I_i= the value of index for each parameter [20].

In case the numbers of parameters measured are less than 11 parameters as mentioned in Table 3, the equation 1 is applicable and does not require any correction. Table 4 demonstrates a descriptive equivalence based on Iran Water Quality Index [20].

Table 4: Descriptive equivalent of Iran Water Quality Index

Index Value	Descriptive Equivalent
<than 15	Extremelypoor
15-29.9	Poor
30-44.9	Relatively poor
44-55	Average
55.1-70	Relatively good
70.1-85	Good
>than 85	Extremely good

2.4. Statistical Analysis

Statistical analysis which has been performed on the data has been done by the software SAS 9.2 [21]. Statistical test that have been performed on the data were paired T test by utilizing the PROC T-test in order to compare the average measured parameters and surveying the significant differences between them in the various stations. For this purpose, the measured parameters during the varied seasons were considered as treatment and the sampling stations throughout the watercourse as repetitions. Another test was a Principal Component Analysis (PCA) by utilizing PROC Princomp, in order to gain awareness as to the type of correlation between the parameters, by taking into consideration the connection of the all the parameters and similarly, a reduction in the data volume by determining the major and critical parameters. In order to survey the procedural changes of the parameters throughout the period of study, the regression analysis was utilized. The fitting regression in relative to June 22 was appraised. The drawing of charts was performed by the Excel Software and the significant survey of R^2 was carried out by the Sigma Plot 12.0 Software.

3. Results and Discussion

3.1. Physico-chemical parameters of watercourse

The physico-chemical parameters under survey in this research comprise of pH, phosphates, nitrates, ammonia, TSS, TDS, EC, turbidity, BOD_5,and COD (Table 5). In general, the amount of pH did not undergo a significant change throughout the sampling period in the various stations. The amount of parameters of phosphates, nitrates and ammonia was respectively between 0.31 to 2.04 mg/l, 3.8 to 25.9 mg/l and 2.15 to 26 mg/l. The fitting regression results in relative to phosphates and nitrates illustrate that, with the passage of time from the summer of 2011 to spring 2012, these two have shown a significant increment at the confidence level of $p<0.01$ (Fig. 2). The elevated changes in the two parameters, namely, TSS and turbidity throughout the sampling period were respectively 120 to 600 mg/l and 6.39 to 565 NTU. This shows that the amounts of these two parameters were absolutely affiliated to the season. As illustrated in (Fig. 2) the procedural changes of these two parameters was on the rise during the passage of time. Such that, by passing from the summer towards the second half of the year and thence, spring, concentrations of the two parameters have increased.
The procedural changes of the two parameters, namely, TDS and EC which are between 400 to 496 mg/l and 597 to 807 µS/cm respectively, are demonstrated in (Fig. 3). It can be noted that this has an incremented mode and is at the confidence level of $p<0.01$ which is significant. The COD changes range was between 28 to 128 mg/l. This is in the condition that the parameter of BOD_5 throughout the watercourse under study was not worth of consideration and its amount varied between 1 to 10 mg/l. Though, the procedural changes in each of the two parameters, considering the various seasons of the year, which have been denoted in (Fig. 3) show reduction; such that, with the passing of a day in the study period, the figures 0.19 and 0.019 mg/l show a reduction in their concentration.As shown in the results attained in the measuring of the physico-chemical parameters, the amounts of the entire of these parameters, throughout the sampling period from the watercourse is of a high study. There is a possibility that the amount of physico-chemical parameters in this watercourse is much more under the impact of human sewage discharges and industrial wastewaters. Statistics indicate that more than nine percent of the industrial foundries of Tehran are located in Zone 15 of this city. This unfortunately, leads to the entrance of a large volume of industrial wastewaters into the Sorkhe-Hessar Watercourse [22].

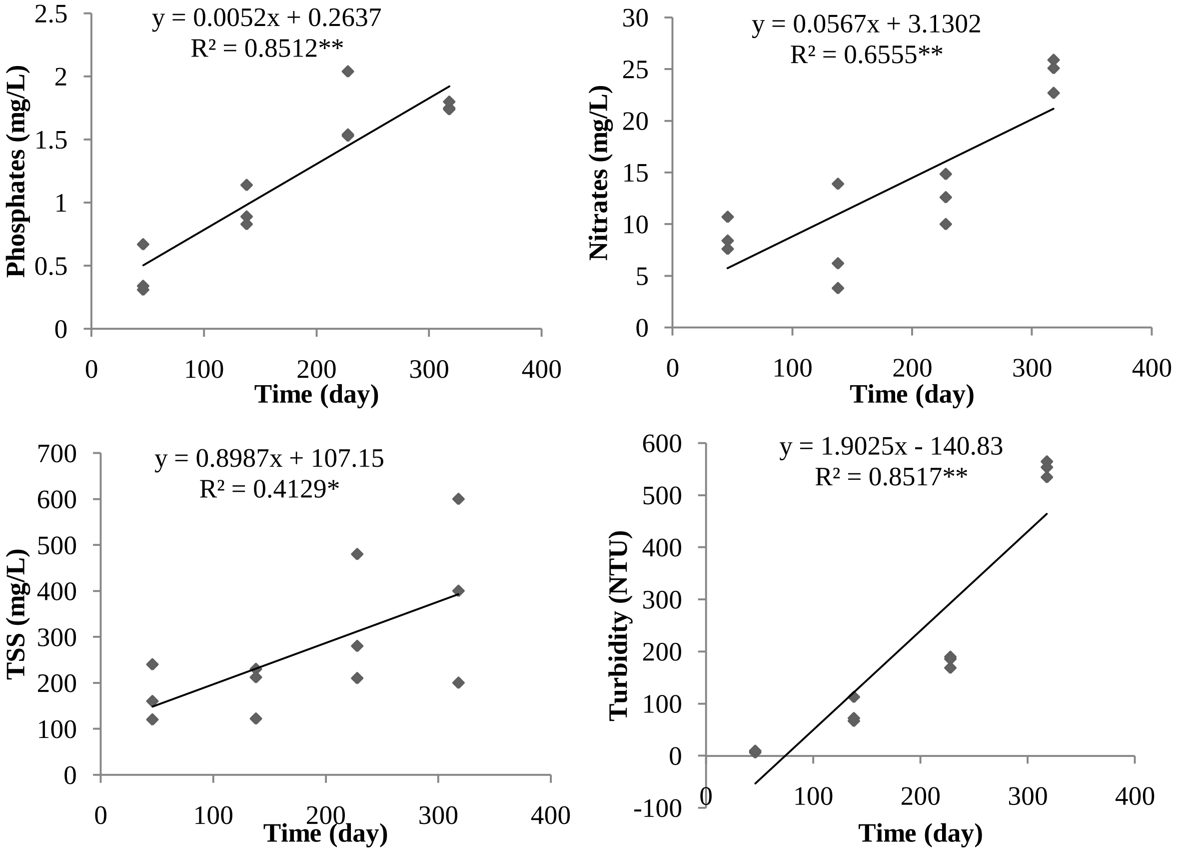

Figure 2: The procedural changes of Turbidity, TSS, Nitrates and phosphates throughout the period of study

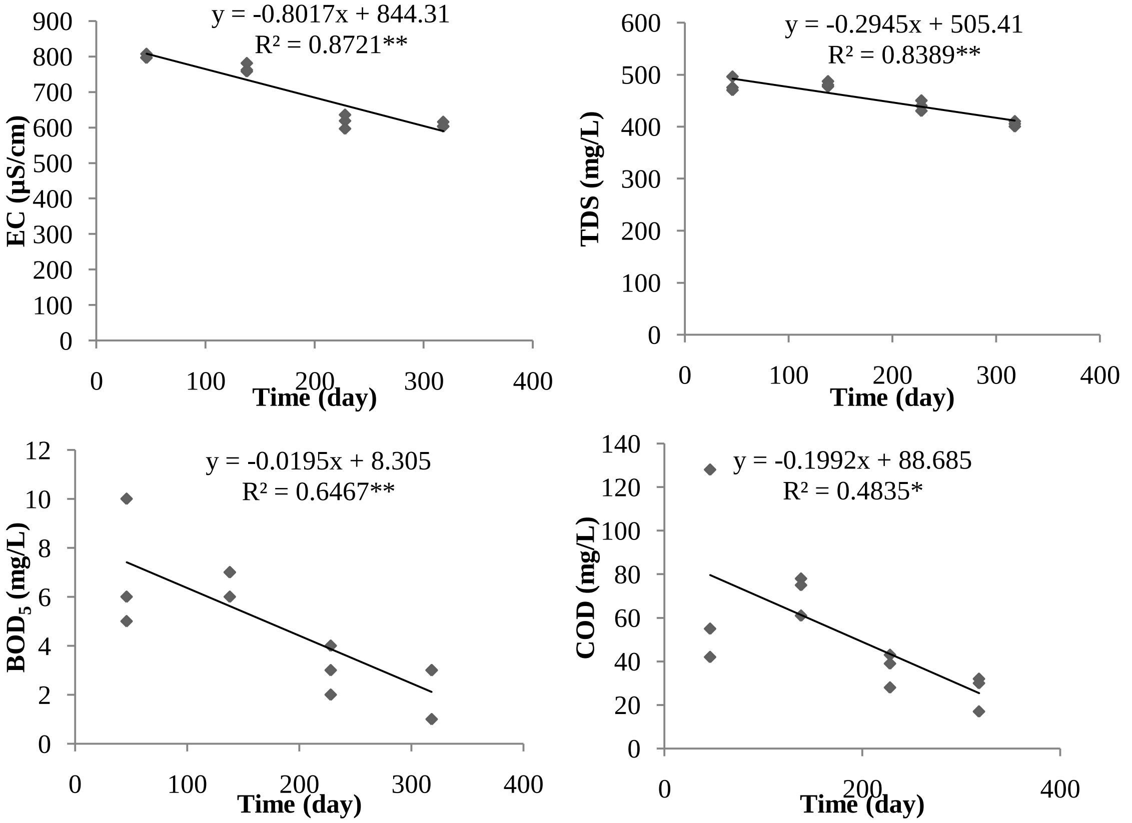

Figure 3: The procedural changes of EC, TDS, BOD_5 and COD throughout the period of study

The high amount of turbidity and TSS, particularly, in the wet season (winter and spring) (Fig. 4) could be because of an increase in the volume of runoff and resulting in the purging of pollutants and suspended particles from the city surface; and likewise, soil erosion in constructional areas throughout the route of the watercourse. In studies which have been performed in other canals and urban rivers, factors increasing turbidity and TSS have been referred to soil erosion arising from wind and precipitation, uncovered wastes that are left in areas, the transfer of suspended particles from the city surface by runoff [23,24]. Similarly, in another research which was carried out by Palamuleni (2002), it was observed that activities performed throughout the urban rivers, has led to an increase the physical pollution load of the water, and the high amount of turbidity and TSS in the wet season in respect to the dry season was attributed to soil erosion due to increasing the volume of urban runoff [25]. Observations relative to Mvungi et al (2003), has also shown that, the source of urban river pollution is probably the mode of managing solid waste in the city outskirts; and that, canal beds are utilized as locations for the burial of solid wastes [26]. This problem also exists in the study area in this research, as the local residents discharge their wastes in such a manner and in addition to incrementing the physical load of pollution, this also leads to the creation of visionary pollution in the region.

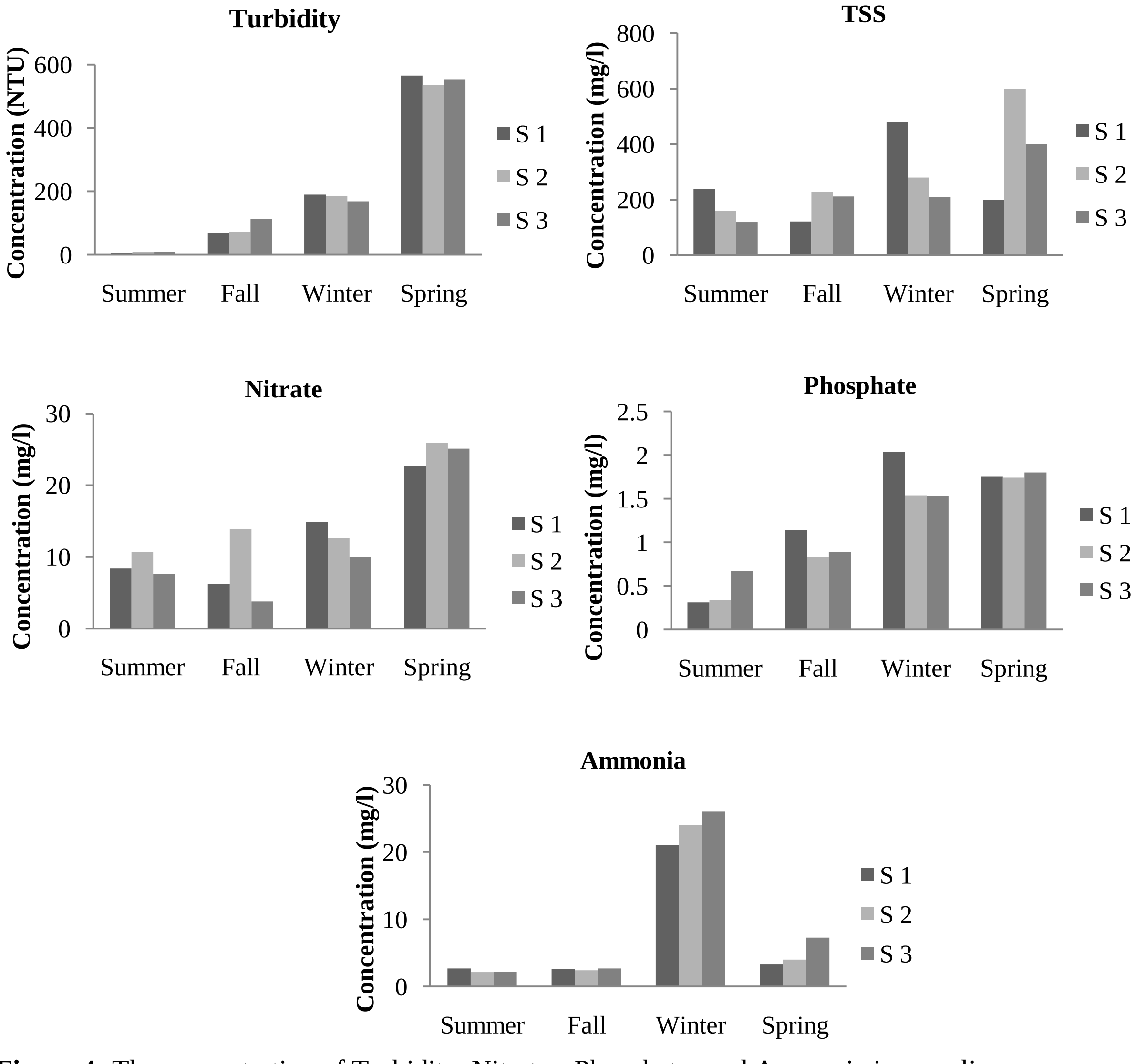

Figure 4: The concentration of Turbidity, Nitrates, Phosphates and Ammonia in sampling seasons

Other researchers in their studies, in relevance to canals and urban rivers, have made indications to this problem that the cause of an elevated amount of chemical parameters such as, COD and nutrients such as, nitrates and phosphate in urban water resources are the discharge of domestic sewage and industrial wastewaters [27-30]. In the current research, the amounts of nitrates, phosphates and ammonia in the wet season (winter and spring), has a considerable increment (Fig. 4). This problem has also been noted in the studies of Girjia et al (2007) and

Fytianos et al (2002).This is probably due to the increased volume of runoff and thus carrying pollutants from the urban surface by these runoff [11,31].

The high amounts of COD and BOD_5 was in the summer and they decreased during the precipitation period (winter and spring) (Fig. 5). This issue that also seen in the study of Bhadja and Vaghela (2013) [32], could be because of the diluting effect of organic matter present in the watercourse due to the effects of rains. Studies of Kumar and Reddy (2009) and Khalik et al (2013) also confirm this matter [8,33]. As mentioned, the parameters of BOD_5 throughout the route of the watercourse under study did not have a considerable amount. The most amount of this was the second station in the length of the watercourse (Table 5). It is possible that the reason for this, as per the confirmation of Al Bakri et al (2008) in their researches also stated, the discharge of human sewage arising from this station, due to its being located in a residential area with the densest population [24].

The high amounts of TDS and EC throughout the dry seasons (summer and autumn) seasons (Fig. 5) could be due to water evaporation of the watercourse, followed by a decrease in water volume. This leads to an increment in mineral concentrations, followed by an increase in TDS and EC [11,33]. Similarly, Owens and Niemeyer (2006) in their research stated the high concentrations of TDS, was due to the human sewage discharge, arising from residential locations in the region and the surrounding industries [34].

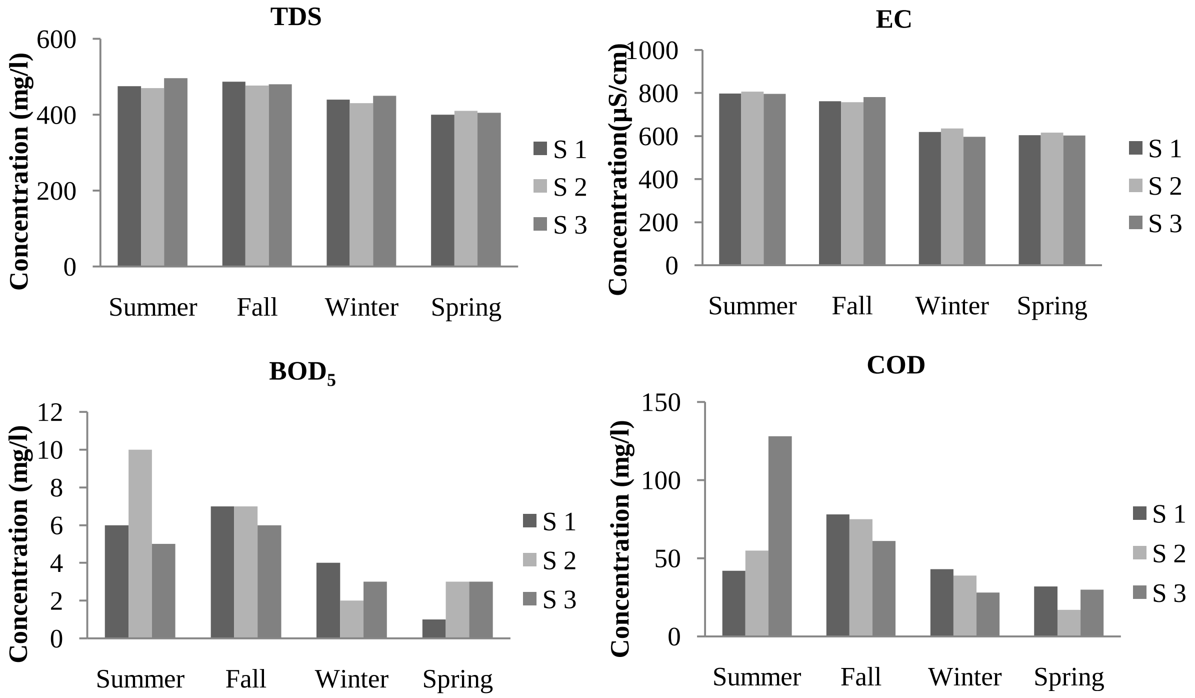

Figure 5: The concentration of EC, TDS, BOD_5 and COD in sampling seasons

3.2. Biological parameters of watercourse

The biological parameters in this study are faecal coliforms and total coliforms. In the entire seasons of study, the amount was more than 1100 MPN/100 ml of the watercourse (Table 5). This is in condition that, based on the guidelines of WHO, the acceptable level of faecal coliforms in the using wastewaters for irrigating vegetables, which are consumed raw, 1000 MPN/100 ml of wastewater has been recommended [35]. It seems that the cause for an elevated amount of coliforms in the watercourse is the passing of the watercourse through a densely populated urban area, resulting in the human sewagedischarge in this area. In this region more than 216 million liters of water is consumed daily which, by enforcing 75percent coefficient for sewage production, approximately 162 million liters of sewage is produced in the area daily [22]. In noting the fact that about 15percent of the sewage produced in Tehran, are discharged in the canals and watercourses, in the study area it is approximated that 24 million liters of sewage is discharged daily into the watercourse and canals. Other similar researches are factors for the increment of total coliforms and faecal coliforms, passing through urban areas and the discharge of human sewage, caused by poor design of wastewater collection systems [36-38]. According to this research and also the studies of Chou (2013) and Lamia (2012) a complete network for the collection of sewage in urban areas, must be a priority for improving urban watercourse quality [39,40].

Table 5: Mean physiochemical characteristics of water samples from Sorkhe-Hessar watercourse and T-student test results for sites

Parameters / Site	pH	EC (μs/cm)	Turbidity (NTU)	COD (mg/l)	BOD_5(mg/l)	TDS (mg/l)	TSS (mg/l)	NO_3 (mg/l)	NH_3 (mg/l)	PO_4 (mg/l)	Feacal coliform (MPN/100ml)	Total coliform (MPN/100ml)
S1	8.15	695.5	207.1	48.75	4.5	450.5	260.5	13.03	7.40	1.31	>1100	>1100
S2	8.12	704.3	200.7	46.5	5.5	446.8	317.5	15.77	8.14	1.11	>1100	>1100
S3	8.07	694.3	211.4	61.75	4.25	457.8	235.5	11.62	9.54	1.22	>1100	>1100
t-value (S1,S2)	0.28^{ns}	-0.13^{ns}	0.04^{ns}	0.14^{ns}	-0.44^{ns}	-0.15^{ns}	-0.46^{ns}	-0.54^{ns}	-0.11^{ns}	0.39^{ns}	-	-
t-value (S1,S3)	0.74^{ns}	0.02^{ns}	-0.02^{ns}	-0.51^{ns}	0.16^{ns}	-0.26^{ns}	0.26^{ns}	0.24^{ns}	-0.30^{ns}	0.19^{ns}	-	-
t-value (S2,S3)	0.53^{ns}	0.14^{ns}	-0.06^{ns}	-0.58^{ns}	0.63^{ns}	-0.43^{ns}	0.72^{ns}	0.72^{ns}	-0.18^{ns}	-0.26^{ns}	-	-

^{ns}No significant difference between treatment pairs at the 0.05 level

Table 6: Principal Component Analysis for mean physicochemical characteristics in Sorkhe-Hessar watercourse

Parameters	PC 1	PC 2
pH	0.14	0.61
EC	-0.38	-0.08
TDS	-0.37	0.13
TSS	0.29	-0.03
COD	-0.31	-0.11
BOD_5	0.32	0.01
NH_3	0.19	0.58
NO_3	0.32	-0.34
PO_4	0.36	0.06
Turbidity	0.34	-0.33
Eigen-values	6.31	1.91
Partial variance	0.6313	0.1916
Total variance	0.6313	0.8229

3.3. Iran Water Quality Index (IRWQI)

In order to compute the water quality index of the watercourse, a number of 9 qualitative parameters have been utilized. These are namely, pH, EC, BOD_5, COD, turbidity, nitrates, phosphates, ammonium and faecal coliform. The index amount obtained from the classified curves [20], with due attention to the measured parameters in the sampling stations (Table 5), can be observed in (Table 7).

Table 7: Values of water quality parameters measured in each sampling stations throughout the period of study

parameters	pH	EC (µs/cm)	Turbidity (NTU)	COD (mg/l)	BOD_5 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)	NH_4 (mg/l)	Fecal coliform (MPN/100ml)
Summer	97	58	71	12	48	8	40	22	26
Fall	97	60	34	14	51	10	23	20	26
Winter	71	66	21	37	76	4	57	1	26
Spring	97	67	8	48	81	1	57	12	26

The results relevant to calculating the water quality index of the watercourse, by considering the average water quality parameters under survey throughout the sampling seasons (Fig. 6), show the water quality index the watercourse in the entire sampling seasons is within the limits of 15-29.9 (classification 6) which reflects poor and polluted conditions. Amongst the sampling seasons, the lowest value of water quality index as shown in the studies of Bhadja and Vaghela (2013) and Khalik et al (2013), pertained to wet seasons (winter and spring). This is because of the high volume of runoff [32,33]. It means heavy rainfall with transported many pollutants into the watercourse, has significant negative effect on deterioration of the watercourse quality[41].

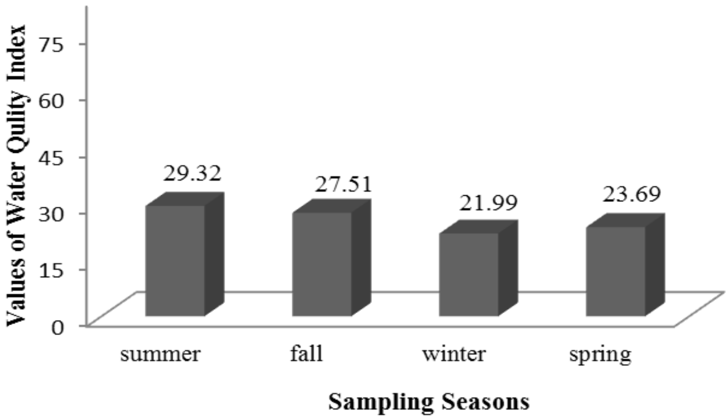

Figure 6: Value of Iran Water Quality Index of the watercourse in sampling seasons

The possibility goes that the location of the watercourse under study in the poor quality of the Iran Water Quality Index could be because of the discharge of sewage and industrial wastewaters, due to the watercourse's passing through the urban area. As Kumar et al (2011) in their studies reasoned that the placement of the Kharikut Canal (India) is classified as extremely poor in the NSF Water Quality Index. This is due to the discharge of domestic, agricultural and industrial sewage to this water area [13]. In Iran, a calculation of water quality index in the Mehran Rood Watercourse in the city of Tabriz illustrated that, in 90percent of the cases, the qualitative index was lower than the mediocre level, reflecting an undesirable state for the watercourse [42].

3.4. Statistical Analysis

The results attained from the paired T-test in order to compare the mean of the parameters measured in the various stations and the survey of their significance (Table 5), show that between the average of these parameters in the sampling stations throughout the watercourse a significant difference did not exist. But generally, as expected, in the second station, in respect to the two other stations, due to its being located in the densest populated area was the most polluted. An absence of significant difference in the varied stations, demonstrates that the pollution of this watercourse is probably for a large extent under the impact of the upstream region.

The results relative to the Principal Component Analysis (PCA) test (Table 6) show that the parameters EC, TDS, COD, BOD_5, nitrates, phosphates and turbidity with a coefficient more than 0.3 in the first component group, had the most share of changes being 63percent and was accounted for as a part of the major factors. Among these parameters, EC, TDS and COD have a contrary connection with the other parameters. This is in such a manner that, with their increase, the other parameters decreases. The increment of these parameters is relevant to the summer and autumn seasons (Fig. 5) as in the mentioned seasons the amount of other parameters are less (Fig. 4). 19percent of the changes are in relevance with the parameters of pH and ammonia, which have the most shares in the second component group.
The present research and other similar studies showed that, the potential pollution sources of the urban watercourses are point source pollutants, such as industrial and domestic wastewater, as well as non-point source pollutants such as urban runoff [43]. Temporal changes in the quality of the studied watercourse like inother studies may be estimated by considering natural processes such as precipitation, as well as anthropogenic sources, particularly discharge of urban, agricultural and industrial wastewaters [44-46]. In general, urban and industrial wastewater, discharge form a sustainable polluting source, whereas, urban runoff are a seasonal phenomenon, influenced highly by the climate [47].

Conclusion

As expected, the results that obtained from the current research has shown that the high pollution load in the Sorkhe-Hessar Watercourse and its categorization being at a poor qualitative level in the Iran Water Quality Index in which it is equivalent to (IRWQI = 15-29.9) and also the watercourse quality in the second station is the most polluted in comparison with two other stations because of its location. Likewise, the watercourse quality analysis indicated the pollution level during the wet seasons was higher than the dry seasons due to the high volume of runoff. Generally two deficient factors: weak designed systems for sewage collection, (with due attention to the fact that 15percent of the sewage produced in Zone 15 of Tehran runs into the watercourse under study); and inappropriate management decisions about urban runoff has led to the pollution of this aquatic zones. In addition to the difficulties regarding the discharge of wastewaters and the entrance of contaminated urban runoff, other problem is dumping waste into it by local residents; that has caused unpleasant scenery as well as an obnoxious odor in the region. Results relative to the PCA test has shown that the parameters of EC, TDS, COD, BOD_5,nitrates, phosphate and turbidity have the most shares in changes *i.e.* 63percent and are accounted for as a part of the main factors. Since the first four parameters were accounted as high in the summer and autumn seasons and the other three parameters show an increase in the seasons of winter and spring; thereby, awareness as to the qualitative conditions of the watercourse throughout the year, in order to control its qualitative circumstances and conserving it from any kind of pollution, is an essential matter. In particular that, the watercourse under study enters the plains of southern Tehran and is utilized for irrigational purposes.
The enforcement of managerial amendments for runoff within structural and non-structural procedures and by implementation of projects for collection and reuse of runoff (*e.g.* constructing green roof for houses with objectives of collecting runoff and securing a part of the domestic water requirements, such as, irrigating green space etc.,); controlling the entrance of pollutants and wastewaters into the urban watercourses by completing the wastewater collection network, the affixing of numerous mesh size nets with different filtering grades to entrap wastes throughout the watercourse, and washing and dredging the watercourse prior to the commencement of precipitation, not only enhances the urban beauty and attractiveness in the way of tourism which is effective; but, in the case of it being turned into a permanent watercourse to secure a part of the urban water requirements (such as for public use, green space, etc.). It increases the utilization efficiency of the runoff and reduces the risk involved with the problems of the occurrence of floods after sudden rainfall, plays a very impactful role in the future visioning of the city.
This research demonstrates the qualitative conditions of the Sorkhe-Hessar Watercourse in brevity. Though, in order to assess the exact and detailed conditions of the watercourse further researches are required, so as to consider the hydrological and climatic changes with frequent sample takings and similarly, a survey of the conditions of pollution in the upstream region is essential.

Acknowledgements

Sincere thanks to all the experts of the Municipal Zone No. 15 of Tehran city, who helped and assisted in performing this research.

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