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Research article

ASSESSMENT OF KHORASAN STEEL COMPLEX IMPACTS ON GROUND WATER RESOURCES OF NEYSHABUR PLAIN OF IRAN, USING WATER QUALITY INDEX AND STATISTICAL METHODS

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ABSTRACT: Khorasan Steel Complex is in the North of Neyshabur Plain, located at a distance of 15 kilometers from North West of the Neyshabur city. The Steel complex produces waste water that is used in adjacent agricultural lands and also generates mixed wastes, including slag, dust, sludge, metal shells and the oxide layers; so, it can be considered as a potential source of pollution. In this study, the Water Quality Index (NSF WQI) and the negative effects of this Complex on the adjacent ground water resources have been evaluated. In this context, 9 parameters used for calculating index, including dissolved oxygen, fecal caliform, turbidity, pH, biochemical oxygen demand, temperature, phosphate, nitrate and total dissolved solids were measured at six stations around the Steel Complex and were used in calculations. In all cases the water samples had a mean Water Quality Index (NSF WQI = 48) lower than the great and the good classes. The samples that located upstream of the Steel Complex have better quality indices (NSF WQI = 52) than samples of the Steel Complex downstream (NSF WQI = 37). Therefore, according to the importance of drinking water resources and agricultural water supply for villagers of the area, the appropriate measurements for preventing further water resources contamination must be considered.

Keywords: Ground Water Resources, Water Quality Index, Waste, Khorasan Steel Complex

INTRODUCTION

Water is a natural, renewable and dynamic resource [10].Today, due to high population growth and the consequent increase in industrial and agricultural activities, ground water and surface water resources are vulnerable and at the risk of contamination. Given the importance of ground water resources in human life, especially in a country like Iran that is known as a country with a rid and semiarid climate which it's annual ground water abstractions is ranked fifth in the world [12], Investigation and assessment of ground water pollution sources is very important. One of the factors used to determine the quality of water resources is Water Quality Index. The index first proposed and presented by Horton (1965). He introduced the Water Quality Index (WQI) as a way to describe the overall condition of the water by rating the different parameters involved in water quality that can be achieved by mathematical calculations. In other words, Water Quality Index can be defined as classified water samples which results from combination of several different parameters affecting the quality of water the time [14]. After further investigation, 9 parameters, as the main factors affecting water quality, were used to calculate the index [1]. These 6parameters include dissolved oxygen, pH, biochemical oxygen demand, temperature, total phosphate, total nitrate, turbidity, total dissolved solids and fecal caliform. According to Miller (1986), Water Quality Index is the dimensionless number that results by normalizing the data of the desired parameters and weighting them. The index being calculated using mathematical correlation makes it possible to perceive the results for everyone. Other researchers around the world have also been doing researches on this concept, each in a specific case and different changes have been proposed to modify and reform the original formulation. [3,11,19,17,4,23,7,22,20,2,6,16]. In this paper we consider the Water Quality Index that was proposed by Brown (1970) and later was introduced by the National Sanitation foundation that was approved and registered by NSF WQI.

MATERIALS AND METHODS

Geology of the study area

The study area is in the North East Iran and is located in the central part of Khorasan Razavi Province. Khorasan Steel Complex is located in Neyshabur west plains catchment, at a distance of 15km from the Neyshabur city in the north- west that is in South of Binalud Mountain, located on1, 400 hectares of land. In terms of geographical location within an area of 58° 42′ E longitude and 36° 21′ N latitude (Figure1). Neyshabur Plain is one of the most important fields of agricultural development and population density of Khorasan Razavi Province. The annual withdrawal amount is about1.2 billion cubic meters. Neyshabur Plain groundwater resources includes 2396 deep and half deep wells, 908 springs and 832 ants with various uses in agriculture, domestic, industrial and live stock. Existing wells in the study area have high depth water tables which are located at a depth of 120 meters in some cases. This makes it be less vulnerable to the impact of the contaminants [9].

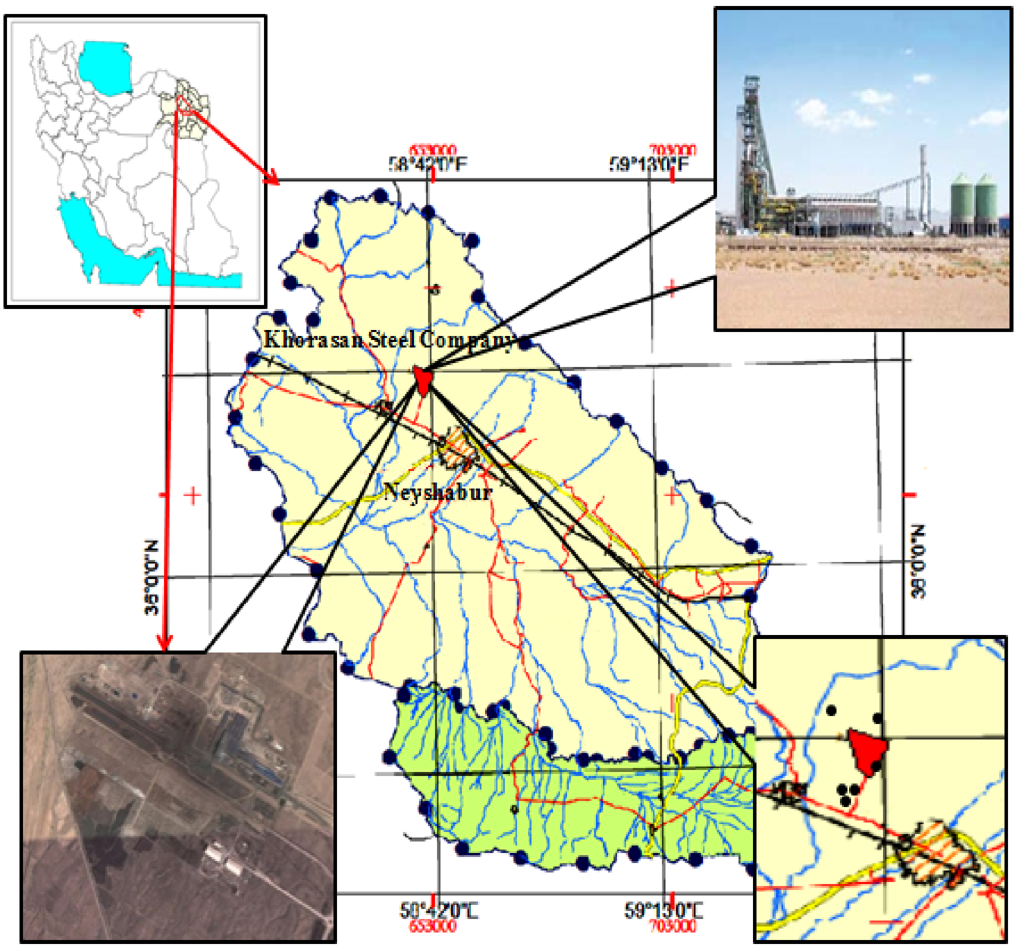

Figure 1. Location of study area

According to geological characteristics, Khorasan Steel Complex is located in south of Binalud highlands which is a part of eastern Alborz section. In the heights of Binalud, units are including J1, Qt2, Ngst, Pzosh, E2m, Ngv, Plqc, Mm and is Evb. Degradation product of these units are flood plain coarse sediment of present covenant that start from north parts of Steel Complex and continue to the central parts of Neyshabur plain and at the end gradually turn into fine sediments in the central plain. Part of the unconfined aquifer that is composed in the alluvial plain of Neyshabur, is the subject of this research. In Figure 2 Geological map of the study area and location of sampling points relative to the complex are shown.

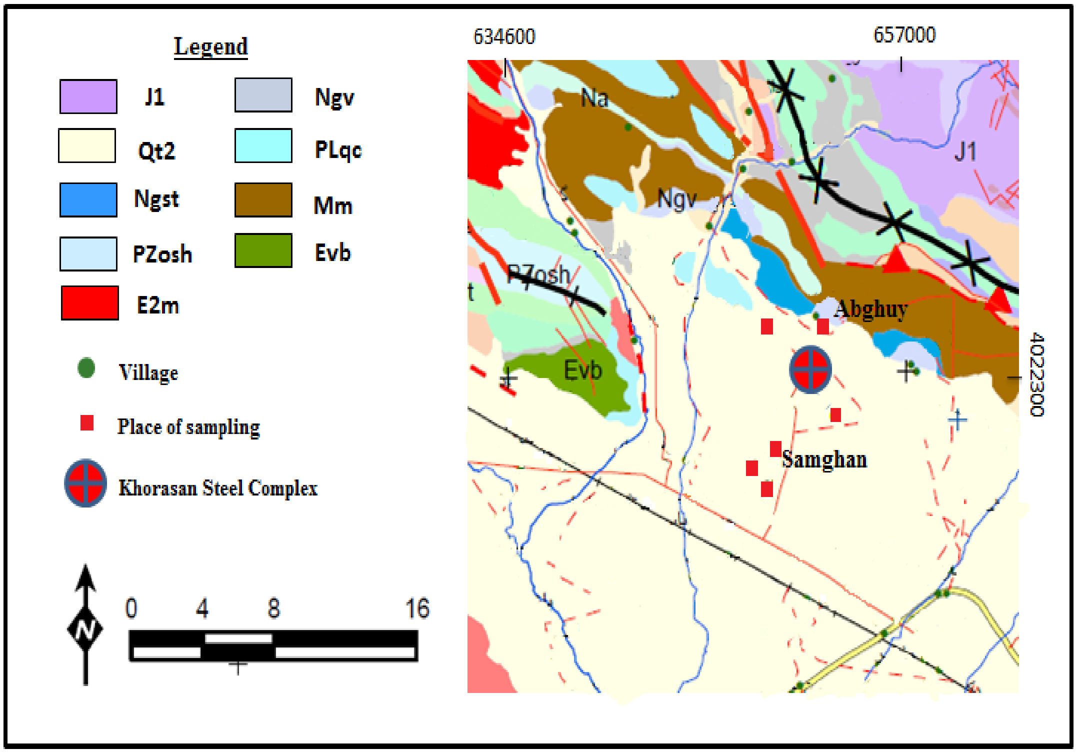

Figure 2. Geological map of the study area

In order to assess the Water Quality Index (WQI) of the study area (surrounding areas of Khorasan Steel Complex), ground water samples from various sources such as springs, wells and qanats were collected, from water sources of Abghooy village (located upstream of the complex), Samghan village (located downstream of complex) as well as existing wells on downstream lands of this complex was performed. Samples were collected based on (Institute of Standards and Industrial Research of Iran, Standard 2347), for measuring parameters required in the calculations.
To measure chemical parameters of each station, 250 ml of water, was filtered and then stored in polyethylene containers and immediately transferred to the laboratory. It should be noted that separate samples were taken for analysis of biological factors. To measure pH, temperature and electrical conductivity of the samples, respectively, during the sampling devices such as, thermometers, pH meters and EC meters were used (pH-meter- model E603 Metrohm, EC-meter GLP 32). Turbidity was measured by Nephelometric method, nitrate by ultraviolet spectrophotometry, phosphate by stannous chloride method, dissolved oxygen by Winkler method, biochemical oxygen demand by using potassium permanganate and finally fecal coliform was calculated by counting in collected samples.

RESULTS AND DISCUSSION

Calculation of Water Quality Index

To determine Water Quality Index in the study area 5 stages were performed. First, the parameters that affect water quality in water samples were measured. At this point, the allowable values for these parameters were determined for subsequent steps. Necessary parameters or the pollution investigation in the surrounding area of Neyshabur Steel Complex, were determined as 9 parameters including: dissolved oxygen, pH, biochemical oxygen demand, temperature, total phosphate, total nitrate, turbidity, fecal caliform and total dissolved solids.

Table 1. Standard values and the weight parameters Water Quality

No.	Parameters	Standards	Units	Recommended Agency	Weigh
1	Dissolved Oxygen (DO)	<82%	Sat%	WHO	0.17
2	Fecal Coliform	<4	FCU/100mg	WHO	0.16
3	Turbidity	4	NTU	USEPA	0.08
4	pH	6.5-8.5	pH units	WHO	0.11
5	Biochemical Oxygen Demand (BOD)	0.8	mg/L	USEPA	0.11
6	Temperature Change (ΔT)	<17.8	˚C	USEPA	0.10
7	Total Phosphates	0.05	mg/L	USEPA	0.10
8	Nitrates	0.5	mg/L	WHO	0.10
9	Total Dissolved Solids (TDS)	500	mg/L	WHO	0.07

In the second step of calculating the quality index, weighting of the measured parameters was performed. Michel (1986) in his book, "hand book for monitoring water quality", suggests that after the National Sanitation Foundation of America next researches, with help of 142 individuals representing a broad range of academic levels, local, state and national level, after investigation among about 35 parameters involved in water quality, finally, nine parameters were considered more important than other parameters; So by the compound of value and their role in polluting the water, they considered a fixed weight for each one (Figure 3). The desired weights for the measured parameters are presented in Table 1.
In the third step, sub-indices for each parameter were calculated by comparing them assured values for each parameter with the index values curves that are plotted for the same parameters. Measured values for each parameter are proposed in Table 2 with initial data analysis to understand how the data distribution is. Sub-index values for each parameter are calculated and presented in Table 3.

In the fourth step, the Water Quality Index calculated by the equation number (1) was performed. In this equation, the NSF WQI is Water Quality Index, Qi as the parameter sub-index forth parameter and was the relative weight forth parameter. NSF WQI values that are calculated for six samples in the study area are presented in Table (3). Equation (1):

$NSF\ WQI = \sum_{i=1}^{n} Wi\ Qi$ (Brown et al., 1970)

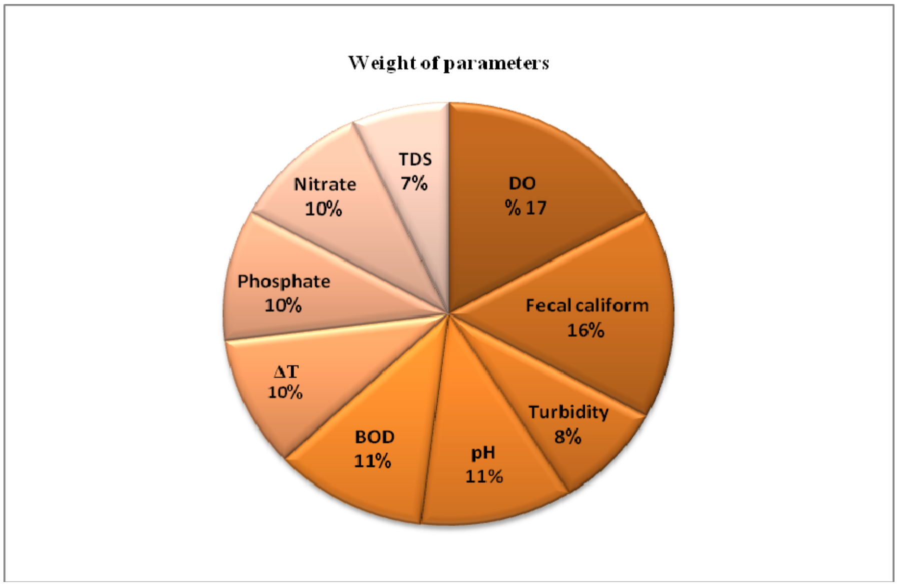

Figure 3. Pie Chart of weight attributed to the 9 parameters

Table 2. Raw measurements with statistical analysis for understanding data distribution

NO.	Parameters	Units	Samp.1	Samp.2	Samp.3	Samp.4	Samp.5	Samp.6	min	max	Mean	median	Std.dev
1	Dissolved Oxygen (DO)	Sat%	4.1	4.4	6.1	5.2	3.1	3.5	3.1	6.1	4.40	4.25	1.1063
2	Fecal Coliform	FCU/100mg	2	1	0	0	18	5	0	18	4.33	1.5	6.9474
3	Turbidity	NTU	0.296	2.11	1.6	8.8	51.2	25.1	0.296	51.2	14.85	5.45	20.0632
4	pH	pH units	7.97	7.88	7.6	7.71	7.9	7.6	7.6	7.97	7.777	7.79	0.1613
5	Biochemical Oxygen Demand (BOD)	mg/L	27	30	28	28	40	39	27	40	32	29	5.8991
6	Temperature Change	˚C	11	12	12	12	13	10	10	13	11.67	12	1.0327
7	Phosphates	mg/L	0.36	0.42	0.39	0.55	0.66	0.28	0.28	0.66	0.4433	0.40	0.1380
8	Nitrates	mg/L	16.99	10.8	30.9	46.3	51.94	17.1	10.8	51.94	29	24	17.0072
9	Total Dissolved Solids (TDS)	mg/L	431	411	475	560	786	526	411	786	531.5	500.5	136.6934

Table 3. Sub-indices for each parameter and the value of Water Quality Index

NO.	Parameters	Weigh	Q1	WQ1	Q2	WQ2	Q3	WQ3	Q4	WQ4	Q5	WQ5	Q6	WQ6
1	Dissolved Oxygen (DO)	0.17	4	0.68	4	0.68	5	0.85	5	0.85	4	0.68	4	0.68
2	Fecal Coliform	0.16	91	14.56	99	15.84	100	16	100	16	64	10.24	80	12.8
3	Turbidity	0.08	98	7.84	93	7.44	94	7.52	78	6.24	38	3.04	57	4.56
4	pH	0.11	85	9.35	88	9.68	92	10.12	91	10.01	87	9.57	92	10.12
5	Biochemical Oxygen Demand (BOD)	0.11	6	0.66	5	0.55	6	0.66	6	0.66	2	0.22	2	0.22
6	Temperature Change	0.10	45	4.5	50	5	50	5	50	5	56	5.6	40	4
7	Phosphates	0.10	75	7.5	69	6.9	72	7.2	58	5.8	52	5.2	83	8.3
8	Nitrates	0.10	40	4	50	3.7	26	2.6	13	1.3	9	0.9	40	4
9	Total Dissolved Solids (TDS)	0.07	42	2.94	45	1.4	36	2.52	20	1.4	20	1.4	20	1.4
		∑W=1		∑WQ1 =52		∑WQ 1=54		∑WQ 1=52		∑WQ 1=47		∑WQ1 =37		∑WQ 1=46

In the fifth step, measured Water Quality Indices (NSF WQI) were compared with water quality classification table for the index. Classification of water quality of samples based on Water Quality Index is presented in Table 4.

Table 4. Classification of water quality based on Water Quality Index (NSF WQI)

Range of WQI	Quality	Grade	Water Status
90-100	Excellent	A	Excellent Water Quality
70-90	Good	B	Good Water Quality
50-70	Medium	C	Poor Water Quality
25-50	Bad	D	Very Poor Water Quality
0-25	Very bad	E	Unsuitable For Drinking

Based on physical, chemical and biological parameters that are presented in Table 2, Sample temperature at least is 10°C and the maximum temperature is13° C; which reflects the fact that sampling was conducted in autumn and samples were taken in the early morning hours. The average temperature for the samples is considered at12° C. Dissolved oxygen of samples containing 3.1 and 6.1are respectively the minimum and maximum amount of dissolved oxygen which is highly dependent on temperature, a factor affecting the dissolution of atmospheric oxygen in to the water [21]. The average of dissolved oxygen samples is 4.4. Fecal caliform was not observed in some samples but the ground water samples in downstream of the steel complex that is in the appearance of aqueduct has maximum value of fecal coliform with representation of the number 18 and total average of fecal caliform of 1.5 which is likely to be the result of the residential sector of Steel Complex. Turbidity levels in the samples, minimum, maximum and mean respectively are 0.296, 51.2 and 14.85. In all cases, the pH shows alkaline property in a way that the data for pH is at least 7.6, the maximum is 7.97 and the average pH 7.77. Biochemical oxygen demand represents the amount of oxygen required by aerobic bacteria to decompose organic matter that represents at least 27, the maximum 40 and the average 32 in water samples. Phosphate and nitrate measured in nutrients of the water samples are representative of a minimum of 0.28 and 8.10, respectively, in the maximum value of 0.66 and 51.94 are shown, and the average data for phosphate and nitrate, respectively, 0.4433 and 29 have been calculated. Total dissolved solids in the water that represents the total ions concentration in the samples, was measured at least 411, the maximum 786 and average data calculated is 531.5. Water Quality Index values (NSF WQI) was calculated according to step 5 mentioned and is presented in Table 4.

Table 5. The final amount of Water Quality Index for samples

Samp.1	∑WQ1=52	Samp.2	∑WQ1=54	Samp.3	∑WQ1=52	Samp.4	∑WQ1=47	Samp.5	∑WQ1=37	Samp.6	∑WQ1=46

A scan be observed in samples1, 2 and 3 according to the classification, Water Quality Index being higher than 50 and lower than 70, is placed in the category of medium quality and the quality of drinking water is poor. These three samples are placed in Grade C. Samples number 4, 5 and 6 were in the category of bad quality due to the lower number of 50 and being further than 25; and in terms of drinking water the samples are very poor and received grade D. Values of Water Quality Index is shown in Figure 3.

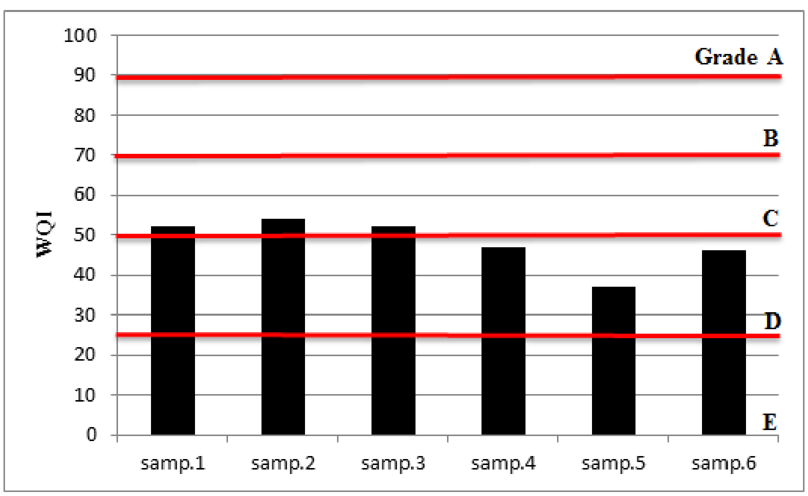

Figure 3. Classification of water samples in the study area according to the Water Quality Index (NSF WQI)

Measured values of samples with 9 parameters and calculated NSF WQI values, were used by SPSS-version 20 software in order to draw Pearson Correlation Matrix to find the possible correlation between the measured and calculated parameters. According to the Pearson correlation coefficient we can recognize effective parameters in fair and poor quality of water samples and seek to removal of the sources of pollutants. The sample correlation matrix is shown in Table 5. Based on Pearson correlation matrix strong correlation between turbidity and total dissolved solids at the 0.01 level and between turbidity and fecal caliform can be observed in a way that in case of increase in the amount of turbidity, total dissolved solids and fecal caliform rises in water. In addition, there is a strong reverse relationship at the 0.01 level between the Water Quality Index, turbidity and total dissolved solids so if the two mentioned parameters, turbidity and total dissolved solids increase in water samples, water quality obviously decreases. High correlation between turbidity and total dissolved solids of the studied samples, indicates that the water quality is greatly influenced by these two parameters and that the source of these parameters should be investigated.

Table 6. Correlation matrix for the measured parameters

Pearson correlation matrix											
		DO	FC	Turbidity	pH	BOD	T	Phosphate	Nitrate	TDS	WQI
DO	Pearson Correlation	1	-.742	-.716	-.463	-.772	.140	-.151	.017	-.488	.607
	Sig. (2-tailed)		.092	.109	.355	.072	.791	.776	.975	.326	.202
FC	Pearson Correlation	-.742	1	.952**	.326	.815*	.409	.603	.527	.891*	-.897*
	Sig. (2-tailed)	.092		.003	.528	.048	.421	.205	.283	.017	.015
Turbidity	Pearson Correlation	-.716	.952**	1	.079	.909*	.293	.561	.580	.931**	-.963**
	Sig. (2-tailed)	.109	.003		.881	.012	.572	.247	.228	.007	.002
pH	Pearson Correlation	-.463	.326	.079	1	-.095	.340	.353	-.055	.078	-.050
	Sig. (2-tailed)	.355	.528	.881		.859	.510	.492	.917	.884	.925
BOD	Pearson Correlation	-.772	.815*	.909*	-.095	1	-.033	.206	.239	.708	-.795
	Sig. (2-tailed)	.072	.048	.012	.859		.951	.695	.648	.116	.059
T	Pearson Correlation	.140	.409	.293	.340	-.033	1	.879*	.669	.519	-.342
	Sig. (2-tailed)	.791	.421	.572	.510	.951		.021	.146	.292	.507
Phosphate	Pearson Correlation	-.151	.603	.561	.353	.206	.879*	1	.859*	.776	-.663
	Sig. (2-tailed)	.776	.205	.247	.492	.695	.021		.029	.069	.151
Nitrate	Pearson Correlation	.017	.527	.580	-.055	.239	.669	.859*	1	.834*	-.747
	Sig. (2-tailed)	.975	.283	.228	.917	.648	.146	.029		.039	.088
TDS	Pearson Correlation	-.488	.891*	.931**	.078	.708	.519	.776	.834*	1	-.979**
	Sig. (2-tailed)	.326	.017	.007	.884	.116	.292	.069	.039		.001
WQI	Pearson Correlation	.607	-.897*	-.963**	-.050	-.795	-.342	-.663	-.747	-.979**	1
	Sig. (2-tailed)	.202	.015	.002	.925	.059	.507	.151	.088	.001	

**. Correlation is significant at the 0.01 level (2-tailed).*. Correlation is significant at the 0.05 level (2-tailed).

Pearson correlation matrix at the 0.05 level in some cases shows too many direct correlation between parameters such as biochemical oxygen demand, turbidity and fecal caliform; temperature and phosphate; nitrate and phosphate; total dissolved solids, nitrate and fecal caliform. Additionally, we can see a large negative effect on water quality by parameter fecal caliform of water samples of studied area at the 0.05 level that is related to the activity of Khorasan Steel Complex.

CONCLUSIONS

In order to assess the impact of Khorasan Steel Complex activities on water resources in Neyshabur plain, samples of the study area in terms of 9 parameters that affect the water quality were analyzed, and the results were evaluated based on Water Quality Index. According to calculations, the maximum amount of Water Quality Index is in the upstream and east of Khorasan Steel Complex (NSF WQI = 54) and the least amount of Water Quality Index is in the downstream of Complex samples (NSF WQI = 37). It can indicate the effectiveness of the complex by waste water and leachate from wastes on quality of downstream water sources. However, the turbidity and total dissolved solids (mean 531.5mg) apply the most negative impact on water quality. Due to the fact that Khorasan Steel Complex is at the first ten years of its activity and considering the point that the water level is very low in aquifer of the study area (over 100 m), we can expect that over time, the impact of contaminants resulting from the plant would be more tangible. In this regard, it is recommended that more detailed examinations of the Khorasan Steel Complex activity be done on the water resources of the region by sampling alternatively.

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