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Comparing the groundwater quality of region 10 of Tehran to the Iranian and EPA drinking water standards

Fatemeh Efati[1] ,Javad Bayat[2]*,Maryam Rouhi Kerigh[3] and Masoume Mollaei[4]

[1] Department of Environmental Planning, Management and Education, Faculty of Environment, University of Tehran, Tehran, Iran
[2] Department of Environmental Pollutants Research, Environmental Sciences Research Institute, Shahid Beheshti University, G.C., Tehran, Iran
[3] Department of Environment, Natural Resources Faculty, Isfahan University of Technology, Isfahan, Iran
[4] Department of Natural Resources and Environment, Science and Research Branch, Islamic Azad University, Tehran, Iran

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Introduction: In recent years, urban development, population growth, and increasing human activities created many problems in the aquatic resources in urban areas. Awareness of the quality of water has great importance due to the increasing need for drinking water in the metropolitan cities. In this study water quality variables were examined to determine the quality of grounwater and the risk of toxic and conventional pollutants in terms of human consumption.

Material and methods: For this purpose, a number of nine wells were selected to investigate the groundwater quality in ward 10 of the municipality of Tehran in the years 2014 and 2016, in the summer and winter. The physical variables including temperature, color, turbidity, and salinity and chemical variables including dissolved oxygen (DO), pH, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), nitrite (NO_2^-), nitrate (NO_3^-), ammonium (NH_4^+), total phosphorus (TP), total nitrogen (TN), sodium (Na), calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), lead (Pb), cobalt (Co), zinc (Zn), and detergent as well as microbial variables were measured.

Results and discussion: The results showed that due to the presence of coliform bacteria and high levels of NO_3^-, the groundwater was polluted by human or animal wastewaters, but there was no serious problem, and it was possible to improve the water quality by processes such as chlorine disinfection. Among the physical variables, only the turbidity was almost twice the standard level in some wells. The Analyses of heavy metals

* Corresponding Author. *E-mail Address*: j.bayat194@gmail.com

showed that the concentrations of Pb, Zn, Fe, and Cu in the groundwater were extremely high, being several times higher than the reported standard level. Changes in TP were very high and reported up to 0.21 mg. Although total coliform and fecal coliform were low, they violated the EPA standard for drinking water. The presence of these two variables in the groundwater is an indication of the penetration of human or animal wastes into the groundwater and, if used, it will cause harmful effects on the health of at-risk people. The total hardness also did not have many fluctuations with a maximum value of 390 mg, which seems fairly favorable, since a concentration of 300 mg is optimal for this variable, and 600 mg is the maximum total hardness of drinking water. The interpolation maps of the groundwater quality index indicated that in the summer of 2014, most of the districts were considered to be in bad and medium conditions, but in the winter of the same year, the conditions changed to medium and relatively good. The water quality index for toxic pollutants in the mentioned seasons and years was in good and very good levels, indicating the groundwater was not polluted by the toxic variables used to determine the index.

Conclusion: The reported data for physiochemical and microbial variables showed that the groundwater in the study area had not serious problems, and only the water turbidity exceeded the standard level. Using chlorine disinfection processes to eliminate coliform bacteria and treatments to reduce water turbidity seem to improve water quality. The calculated groundwater indices for the district water indicated that most of the ward, in terms of conventional pollutants, was in the bad-to-medium category in 2014, while in 2016, the quality category changed to medium to fairly good.

Keywords: Groundwater, 10th Region of Tehran, Water Pollution, Water Quality Index

Introduction

In recent years, urban development, population growth, and increasing human activities have created problems in the aquatic environment in urban regions (Shah *et al.,* 2008; Sekabira *et al.,* 2010). Currently, many countries in the world encounter with water scarcity and its pollutions, as the United Nations Environment Program has introduced the problem of water scarcity and global warming as the major problem of the recent millennium. According to the United Nations report at the Mexico World Summit in 2006, more than 2.1 billion people in the world were deprived of access to drinking water, which was expected to reach 2.8 billion by 2025 and 4 billion by 2050. Groundwater sources contain more than 90% of the drinking water of the entire world and are considered as one of the world's largest storage of water due to their lower pollution potential and high storage capacity. However, these sources have encountered various challenges such as natural and non-natural pollutants over the past years. The water quality of these sources, which is determined based on the type of its ingredients, has particular importance in determining its suitability for uses such as green space and, in particular, urban drinking water. It should be noted that the quality of groundwater depends on factors such as the origin and the chemical reactions between water and the environment in which water flows. Furthermore, the issue of the entry of industrial, urban and agricultural wastewater into the underground water will affect the quality of the water in many ways (Arabi, 1999).

Considering the importance of water in the warm and dry climate of Tehran metropolis and its increasing population growth and uncontrolled increase in various types of environmental pollution, the examination of the groundwater quality as one of the most important cases in determining the quality of the human's life in urban environments seems necessary. One simple analytical method for qualitative water sources assessment is the investigation of the water quality index as a strong management tool in decision-making (Liou *et al.,* 2003; Simoes *et al.,* 2008). This index provides a method to examine the water quality and helps to understand whether the groundwater has a potential hazard for different water uses or not. Furthermore, by investigating water quality indices in different divisions of a city, those with low-quality groundwater aquifers can be considered for more accurate surveys and monitoring programs. In addition, through optimal waste management and control of human activities, the influence of those leading to groundwater sources pollution can be reduced. Analyzing physical, chemical, and biological parameters are mostly used in the investigations on the quality of water (Abdo *et al.,* 2010; Kumar *et al.,* 2011). Several studies and research have been conducted in this regard, some of which are referred in the following.

In Japan, Xaun (2001) introduced the human activities (sewage, garbage, and water of destroyed wells) and natural factors (polluted surface water due to increased TDS as pollutants in groundwater by studying the groundwater pollutant factors. Ramakrishnaiah (2009) compared the groundwater index of the city of Tucmmar in India with the WHO index (WHO, 1998) by examining the quality of groundwater sources. Soleimani *et al.* (2010) stated that in total, the groundwater of the ward 10 of Kohsorkh was in good to acceptable quality in terms of drinking water standards by evaluating the qualitative changes of water sources using GQI qualitative index in the GIS software (Soleimani *et al.,* 2013). Tabatabai et al. (2010) evaluated the groundwater quality in Isfahan city during two sampling stages. Their results showed that all factors were within allowed limit, and the microbial pollution of the river had no effect on the well's water quality. Another study was conducted by Shirani *et al*. (2014) in district 14 of Tehran examining 16 wells located in the district for assessing and identifying the qualitative status of the groundwater sources. They reported that wastewater and using of fertilizer had a greate effect on the accomulation of anionic and cationic pollutants in the grounwater. Eslami *et al*. (2015) studied the quality index of WQI in groundwater sources in Kerman Province in 2015. Their results indicated that this area has a poor water quality based on the WQI index, therefore, water should be treated for drinking uses (Eslami *et al.,* 2015). Nejatijahromi *et al*. (2018) evaluated the quality of groundwater for drinking purposes in Varamin aquifer. They reported that the concentrations of heavy metals were more than the permissible amount for drinking. They concluded that the risk of groundwater contamination, especially heavy metals, continues due to the persistence of contamination sources in the Varamin Plain (Nejatijahromi *et al.,* 2018).

Material and methods

The studied district

Ward 10 is one of the central wards of the municipality of Tehran metropolis, divided into three sub-wards and 10 neighborhoods, which is the second smallest ward after district 17 among the 22 wards of Tehran. The water sources of ward 10 are different on the basis of the type of consumption. The district is entirely covered by the water supply network of drinking water. The share of surface water (water derived from dams) in this district is lower than groundwater sources (wells) in drinking water supply networks. Similar to other districts of Tehran, the most important source of raw and non-drinkable water supply is groundwater sources and extracted water by electric pumps from the wells. Major accessible water sources consist of deep wells, which are used in urban services such as municipal housekeeping e.g. washing the passageways and curbs, irrigation of green spaces, firefighting, and washing big rubbish bins. Fig. 1 shows the studied area and sampling points in Tehran city.

Sampling and the studied variables

The studied physical variables included water's temperature, DO, color, turbidity, and salinity. Chemical variables i.e. pH, EC, TSS, TDS, NO_2^-, NO_3^-, NH_4^+, TP, TN, Na, Ca, Mg, Cu, Fe, Pb, Co, Zn, detergent and microbial variables such as gastrointestinal coliform and total coliform were also measured.

Sampling was carried out in both summer and winter of 2014 and 2016 from nine wells, supplying the water of green space and other activities related to urban services to assess the quality of groundwater in the district in terms of drinking standards. According to the shape of the district, selection of stations was done from north to south and east to west to determine the trend in the quality of groundwater based on the geographical location. It is worth noting that sampling was carried out under weather conditions without rainfall. In addition, sampling was done after three hours of pumping, and the microbial samples were immediately sent to the laboratory. Polyethylene containers (according to the type of parameter) were used to sample the physical and chemical parameters. It should be noted that the proposed guidance by the American Public Health Association (AHPA, 1999) was used for sampling and analyzing the samples.

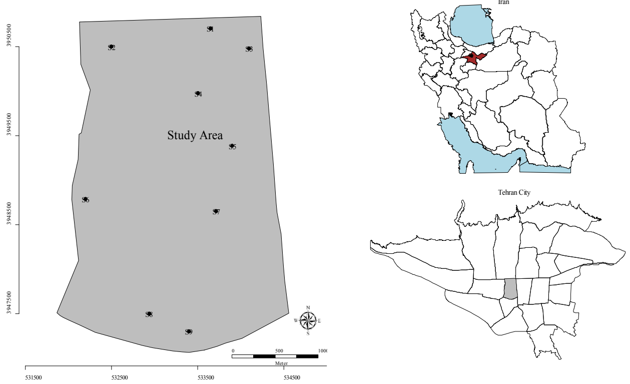

Fig. 1- Study area in Tehran city

Statistical analyses

The mean, median, and range of variables were determined. Furthermore, the Spearman nonparametric correlation method was used to obtain the correlation between variables. Moreover, R software was used for statistical analysis (R Development Core Team, 2011).

Iran water quality index for groundwater (IRWQI)

In this study, Iran groundwater quality index was used to examine the groundwater quality of the studied district. To calculate this index, the weight of each parameter was first obtained, and then the water quality index was estimated using the following formula (1).

$$\gamma = \sum_{i=1}^{n} W_i \qquad (1)$$

Where:

W_i = weight of the i^{th} parameter

n = number of parameters

I_i is the index value for i^{th} parameter obtained from the rating curve

Results and discussion

Examining the results of measured variables

In this study, the results of physicochemical experiments were examined in nine sampling stations in district 10 of Tehran. Tables 1 to 3 show the results of the statistical analyses. As the results show, the range of difference in DO in 2014 was higher than that in 2016; the pH of the water was neutral (slightly toward base) and had no significant differences between two years, and was within the EPA standard for drinking water. The differences in EC were higher in 2014. The water temperature was almost uniform in 2014 and 2016. The concentration of suspended solids and turbidity level was high, and the water in this ward had turbidity twice as much as the standard level at some stations. The amount of dissolved solids was slightly high, and the mean of this variable was higher than the EPA standard. The range of changes in NO_2^- was slightly higher and reported to be 0.9 mg in 2014, but it was in a desirable limit in 2016, and the level of this variable was always below the standard level of the EPA. Low stability was among the reasons for the low concentration of NO_2^- in the water that is rapidly converted to NO_3^-. Changes in water's NO_3^- were high and reported up to 23 mg in 2014. The high level of this variable in the groundwater of the ward 10 was probably due to the high solubility of NO_3^- in water and lack of sediment, which reached the groundwater from the surface along with the flows (Keyhomayoun *et al.,* 2011). Although the concentration of this parameter in the groundwater was high, it did not exceed the EPA standards. The concentration of NH_4^+ was also high. The total nitrogen had a high concentration, indicating high levels of organic nitrogen in groundwater in the study area. Changes in TP were very high and reported up to 0.21 mg. Although the amount of total coliform and fecal coliform were low, they violated the EPA standard for drinking water. The presence of these two variables in the groundwater indicated entrance of human or animal waste into the groundwater which, if used, will cause harm for at-risk people. The total hardness also did not show many differences. The maximum value of this variable was reported 390 mg, which seems fairly favorable in terms of hardness since 300 mg of this variable is optimal and 600 mg is the maximum total hardness allowed for drinking water (Priscilla, 2008). The optimal amount of calcium and magnesium for drinking water is 75 and 30 mg, respectively (Priscilla, 2008). Considering the measured data, the level of these two parameters in the groundwater of the district is higher than the optimal level for drinking water. The optimum concentration of Na in drinking water has been stated up to 50 mg/l, which according to the reported data, the concentration of this variable in the water of the district is approximately twice as much as its optimal concentration. Shirani *et al*. (2013) and Imanzadeh *et al*. (2010) reported that the level of Na in the groundwater of district 14 of Tehran and Kabodar Ahang, respectively, was desirable by examining the groundwater quality. The concentration level of Co, Zn, Pb, Fe, and Cu was very high and was reported up to several times higher than the standard level. The concentration of Fe was about 300 times more than the standard level of WHO. Although both EPA and Iran's standard does not have any limitation for Co in drinking water, the concentration of this compound, especially in 2014, was high. Some institutions have introduced Co as a carcinogen and the standard level of FAO for Co in irrigation water is 0.05 mg/l. Nejatijahromi *et al*. (2018) have reported that the groundwater of Varamin was polluted by Co because of irrigation with wastewater. Due to the high concentrations of these variables in drinking water of the district, there will be harmful effects on the health of citizens such as brain damage, reducing learning power, effects on kidney and liver, and high blood pressure. Shirani *et al*. (2013) reported the concentration of Pb in groundwater of district 14 of Tehran much less than the concentrations obtained in this study. Moreover, Mohammadian *et al*. (2008) reported a high concentration of Pb in the groundwater around Zanjan Lead and Zinc Factory which exceeds the standard level. The amount of detergent was reported only in 2014. Tables 2 and 3 show the correlation between the studied variables in 2014 and 2016. The obtained results indicate that the amount of oxygen dissolved in water was affected by the temperature level and soluble solids. There was a direct and significant relationship between the EC and most of the water-soluble ions (Shirani *et al.,* 2014), especially NO_3^-, which had a high concentration in the groundwater of the district. Nasrabadi *et al*. (2013) also reported that NO_3^- has polluted the groundwater due to human activities. Turbidity showed a direct and significant relationship with microbial variables. Yisa *et al*. (2012) reported a direct and significant relationship between the amount of turbidity and total coliform in Nigeria by analyzing the underground water quality variables. TP represented a significant and direct relationship with detergents due to the presence of phosphorus compounds in the structure of the detergents entered into the underground water of the district. The microbial variables were significantly and positively related to the amount of Fe and detergents; however, in 2016, this relationship was not significant. In this regard, Pb with Ca and Cu with Na showed an inverse relationship, and Cd showed a direct relationship with Na and Mg.

Table 1. Descriptive statistics

Parameters	2014				2016				EPA St Levels for drinking water	Iran St Levels for drinking water
	Mean	Median	Min	Max	Mean	Median	Min	Max		
DO (mg/l)	7	7	6.1	8.38	7.11	6.9	6.5	7.9	-	-
pH	7.52	7.48	7.12	7.96	7.45	7.41	7.11	7.87	6.5-8.5[b]	6.5-8.5
EC (µS/cm)	1016.72	978.5	687	1343	720.11	662.5	498	993	-	-
Temp (C)	21.76	21.55	19.1	25.9	21.64	21.85	18.9	23.4	-	-
TSS (mg/l)	1.72	0	0	15	0.89	0	0	6	-	-
TDS (mg/l)	696.78	659.5	443	956	693.06	656.5	498	899	500[b]	1500
Turb (NTU)	3.87	3.67	0.75	10	3.76	3.49	0.68	10	-	5
NO_2^- (mg/l)	0.02	0.02	0	0.09	0.01	0	0	0.02	3[a]	3
NO_3^- (mg/l)	11.43	9.65	5.12	23.9	9.69	9.65	6	16.74	44[a]	50
TN (mg/l N)	27.16	24.8	9.25	73.8	20.75	18.11	9.1	48.5	-	-
NH_4^+ (mg/l)	0.15	0.16	0.01	0.35	0.14	0.16	0.02	0.3	-	-
TP (mg/l P)	0.11	0	0	0.78	0.05	0	0	0.21	-	-
FC (MPN/100cc)	2.78	0	0	15	1.07	0	0	8	0[a]	-
TC (MPN/100cc)	6.17	0	0	36	2.17	0	0	10	0[a]	-
TH (mg/l)	280.5	287.5	15	390	257	246	180	390	-	500
Zn (mg/l)	9.63	8.5	4.99	17.26	9.38	8.81	5.01	15.25	5[b]	3
Pb (mg/l)	6.32	5.69	1.01	15.64	5.1	4.84	1.24	12.21	0.015[a]	0.01
Fe (mg/l)	45.59	25.9	2.5	115.5	44.98	31.5	4.9	108	0.3[b]	0.3
Cu (mg/l)	8.41	8.04	4.3	14.23	1.82	1.8	0.98	3.6	1[a]	2
Co (mg/l)	0.89	0.54	0	4.27	0.42	0.26	0	1.98	-	-
Na (mg/l)	101	100.5	26	150	118.22	110	49	175	-	200
Mg (mg/l)	14.82	12.75	6.7	25.6	17.57	17.7	6.8	28.5	-	30
Ca (mg/l)	95.11	95.5	76	112	91.22	90.5	79	105	-	300
Deter (mg/l)	0	0	0	0.02	0	0	0	0	-	-

[a]Primary standard
[b]Secondry standard

Table 2. Correlation between studied variables in 2014

Para	DO (mg	pH	EC (µS/	Temp	TSS (mg	TDS	Turb	NO_2^-	NO_3^-	TN (mg	NH_4^+	TP (mg	FC (MP	TC (MP	TH (mg	Zn (mg	Pb (mg	Fe (mg	Cu (mg	Co (mg	Na (mg	Mg (mg	Ca (mg	Deter
DO	1	-0.35^{ns}	-0.39^{ns}	-0.52^{**}	0.19^{*}	-0.6^{**}	-0.46^{ns}	-0.03^{ns}	-0.38^{ns}	0.51^{*}	-0.48*	-0.39^{ns}	-0.31^{ns}	-0.29^{ns}	-0.08^{ns}	0.02^{ns}	-0.08^{ns}	-0.36^{ns}	-0.06^{ns}	-0.50^{*}	-0.49*	-0.53^{*}	0.17^{ns}	-0.42^{ns}
pH		1	0.27^{ns}	-0.02^{ns}	-0.43^{ns}	0.35^{ns}	0.01^{ns}	0.32^{ns}	0.31^{ns}	0.05^{ns}	0.22^{ns}	-0.01^{ns}	-0.25^{ns}	-0.30^{ns}	0.11^{ns}	-0.21^{ns}	0.25^{ns}	0.07^{ns}	-0.16^{ns}	0.19^{ns}	0.32^{ns}	0.34^{ns}	0.07^{ns}	0.02^{ns}
EC			1	0.6^{**}	-0.33^{ns}	0.85^{**}	0.24^{ns}	0.14^{ns}	0.49^{*}	0.24^{ns}	0.73^{**}	-0.02^{ns}	0.10^{ns}	0.09^{ns}	0.61^{**}	-0.12^{ns}	0.37^{ns}	-0.04^{ns}	-0.44^{ns}	0.66^{**}	0.80^{**}	0.71^{**}	0.27^{ns}	0.27^{ns}
Temp				1	-0.30^{ns}	0.70^{**}	0.02^{ns}	-0.08^{ns}	0.54 *	-0.33^{ns}	0.66^{**}	0.27^{ns}	0.04^{ns}	0.03^{ns}	0.28^{ns}	0.16^{ns}	0.40^{ns}	-0.22^{ns}	-0.19^{ns}	0.58 *	0.62^{**}	0.62^{**}	-0.14^{ns}	0.20^{ns}
TSS					1	-0.26^{ns}	0.29^{ns}	-0.12^{ns}	-0.27^{ns}	-0.12^{ns}	-0.21^{ns}	-0.19^{ns}	0.37^{ns}	0.4^{ns}	-0.19^{ns}	0.04^{ns}	-0.41^{ns}	0.28^{ns}	0.19^{ns}	-0.23^{ns}	-0.27^{ns}	-0.24^{ns}	0.25^{ns}	-0.27^{ns}
TDS						1	0.34^{ns}	0.17^{ns}	0.5^{*}	-0.12^{ns}	0.8^{**}	0.13^{ns}	0.13^{ns}	0.11^{ns}	0.36^{ns}	-0.06^{ns}	0.40^{ns}	0.14^{ns}	-0.48^{*}	0.65^{**}	0.95^{**}	0.79^{**}	0.09^{ns}	0.27^{ns}
Turb							1	0.03^{ns}	-0.00^{ns}	0.07^{ns}	0.23^{ns}	-0.03^{ns}	0.68^{**}	0.69^{**}	0.07^{ns}	-0.17^{ns}	-0.18^{ns}	0.52^{*}	-0.08^{ns}	0.09^{ns}	0.31^{ns}	0.32^{ns}	0.44^{ns}	0.38^{ns}
NO_2^-								1	0.47^{*}	0.01^{ns}	0.13^{ns}	0.10^{ns}	0.05^{ns}	0.02^{ns}	-0.13^{ns}	0.03^{ns}	0.39^{ns}	-0.01^{ns}	-0.26^{ns}	-0.32^{ns}	0.17^{ns}	-0.06^{ns}	-0.25^{ns}	0.44^{ns}
NO_3^-									1	-0.11^{ns}	0.45^{ns}	0.37^{ns}	-0.06^{ns}	-0.08^{ns}	0.16^{ns}	-0.19^{ns}	0.40^{ns}	-0.31^{ns}	-0.25^{ns}	0.15^{ns}	0.59^{**}	0.37^{ns}	-0.36^{ns}	0.38^{ns}
TN										1	-0.10^{ns}	-0.6^{**}	-0.22^{ns}	-0.2^{ns}	0.32^{ns}	-0.26^{ns}	0.07^{ns}	-0.33^{ns}	-0.37^{ns}	-0.12^{ns}	-0.01^{ns}	-0.10^{ns}	0.55^{*}	-0.18^{ns}
NH_4^+											1	0.06^{ns}	-0.06^{ns}	-0.07^{ns}	0.50^{*}	0.13^{ns}	0.24^{ns}	0.19^{ns}	-0.6^{**}	0.33^{ns}	0.79^{**}	0.67^{**}	0.24^{ns}	0.1^{ns}
TP												1	0.37^{ns}	0.36^{ns}	0.06^{ns}	-0.28^{ns}	0.01^{ns}	0.16^{ns}	0.34^{ns}	0.06^{ns}	0.00^{ns}	0.27^{ns}	-0.46^{ns}	0.50^{*}
FC													1	0.98^{**}	0.05^{ns}	-0.13^{ns}	-0.22^{ns}	0.47^{*}	0.30^{ns}	0.10^{ns}	0.05^{ns}	0.14^{ns}	0.12^{ns}	0.49^{*}
TC														1	0.01^{ns}	-0.13^{ns}	-0.28^{ns}	0.47^{*}	0.33^{ns}	0.11^{ns}	0.03^{ns}	0.12^{ns}	0.13^{ns}	0.47^{*}
TH															1	-0.18^{ns}	0.10^{ns}	0.06^{ns}	-0.30^{ns}	0.22^{ns}	0.30^{ns}	0.51^{*}	0.55^{*}	0.18^{ns}
Zn																1	0.01^{ns}	0.23^{ns}	-0.11^{ns}	-0.15^{ns}	-0.03^{ns}	-0.35^{ns}	-0.12^{ns}	-0.09^{ns}
Pb																	1	-0.43^{ns}	-0.53^{*}	0.16^{ns}	0.30^{ns}	0.22^{ns}	-0.05^{ns}	0.45^{ns}
Fe																		1	0.03^{ns}	-0.05^{ns}	0.12^{ns}	0.13^{ns}	0.21^{ns}	0.17^{ns}
Cu																			1	0.11^{ns}	-0.58^{*}	-0.21^{ns}	-0.38^{ns}	-0.06^{ns}
Co																				1	0.53^{*}	0.66^{**}	-0.01^{ns}	0.01^{ns}
Na																					1	0.7^{**}	0.09^{ns}	0.11^{ns}
Mg																						1	0.21^{ns}	0.20^{ns}
Ca																							1	-0.05^{ns}

Table 3. Correlation between studied variables in 2016

8	DO	pH	EC	Temp	TSS	TDS	Turb	NO_2^-	NO_3^-	TN	NH_4^+	TP	FC	TC	TH	Zn	Pb	Fe	Cu	Co	Na	Mg	Ca
DO (mg/l)	1																						
pH	-0.10^{ns}	1																					
EC (µS/cm)	-0.14^{ns}	0.34^{ns}	1																				
Temp (C)	-0.60^{**}	0.08^{ns}	0.39^{ns}	1																			
TSS (mg/l)	-0.13^{ns}	-0.16^{ns}	0.09^{ns}	-0.079^{ns}	1																		
TDS (mg/l)	-0.56^{*}	0.43^{ns}	0.78^{**}	0.69^{**}	0.136^{ns}	1																	
Turb (NTU)	0.13^{ns}	0.23^{ns}	0.48^{*}	0.036^{ns}	-0.04^{ns}	0.296^{ns}	1																
NO_2^- (mg/l)	-0.32^{ns}	-0.004^{ns}	0.4^{ns}	0.517^{ns}	0.024^{ns}	0.306^{ns}	0.04^{ns}	1															
NO_3^- (mg/l)	-0.40^{ns}	0.31^{ns}	0.47^{**}	0.69^{**}	-0.154^{ns}	0.496^{*}	-0.12^{ns}	0.73^{**}	1														
TN (mg/l N)	0.69^{**}	0.08^{ns}	0.40^{ns}	-0.456^{ns}	0.056^{ns}	-0.089^{ns}	0.37^{ns}	-0.11^{ns}	-0.188^{ns}	1													
NH_4^+ (mg/l)	-0.44^{ns}	-0.07^{ns}	0.57^{*}	0.608^{**}	0.17^{ns}	0.663^{**}	0.26^{ns}	0.55^{*}	0.333^{ns}	-0.103^{ns}	1												
TP (mg/l P)	0.07^{ns}	-0.34^{ns}	-0.47^{ns}	0.088^{ns}	-0.17^{ns}	-0.43^{ns}	-0.17^{ns}	0.14^{ns}	0.103^{ns}	-0.327^{ns}	-0.004^{ns}	1											
FC (MPN/100cc)	-0.21^{ns}	-0.10^{ns}	0.26^{ns}	0.321^{ns}	-0.187^{ns}	0.234^{ns}	0.59^{**}	0.05^{ns}	0.014^{ns}	-0.135^{ns}	0.151^{ns}	0.135^{ns}	1										
TC (MPN/100cc)	-0.24^{ns}	-0.14^{ns}	0.13^{ns}	0.347^{ns}	-0.235^{ns}	0.122^{ns}	0.51^{*}	0.09^{ns}	-0.018^{ns}	-0.25^{ns}	0.157^{ns}	0.26^{ns}	0.94^{**}	1									
TH (mg/l)	0.05^{ns}	-0.11^{ns}	0.67^{**}	0.14^{ns}	-0.05^{ns}	0.34^{ns}	0.18^{ns}	0.15^{ns}	0.02^{ns}	0.38^{ns}	0.44^{ns}	-0.18^{ns}	0.27^{ns}	0.24^{ns}	1								
Zn (mg/l)	-0.11^{ns}	-0.19^{ns}	-0.02^{ns}	-0.07^{ns}	0.007^{ns}	0.07^{ns}	-0.15^{ns}	-0.17^{ns}	-0.28^{ns}	-0.19^{ns}	0.09^{ns}	-0.20^{ns}	-0.23^{ns}	-0.24^{ns}	0.06^{ns}	1							
Pb (mg/l)	-0.25^{ns}	-0.20^{ns}	0.19^{ns}	0.14^{ns}	0.44^{ns}	0.31^{ns}	-0.27^{ns}	0.12^{ns}	0.11^{ns}	-0.02^{ns}	0.24^{ns}	-0.33^{ns}	-0.08^{ns}	-0.22^{ns}	0.17^{ns}	0.34^{ns}	1						
Fe (mg/l)	-0.22^{ns}	0.07^{ns}	-0.11^{ns}	-0.06^{ns}	-0.08^{ns}	0.09^{ns}	0.37^{ns}	-0.40^{ns}	-0.40^{ns}	-0.35^{ns}	0.11^{ns}	0.25^{ns}	0.47^{*}	0.45^{ns}	-0.01^{ns}	0.24^{ns}	-0.18^{ns}	1					
Cu (mg/l)	-0.05^{ns}	-0.08^{ns}	-0.67^{**}	-0.07^{ns}	-0.28^{ns}	-0.45^{ns}	-0.12^{ns}	-0.44^{ns}	-0.27^{ns}	-0.42^{ns}	-0.53^{*}	0.21^{ns}	0.14^{ns}	0.27^{ns}	-0.5^{*}	-0.12^{ns}	-0.50^{*}	0.18^{ns}	1				
Co (mg/l)	-0.43^{ns}	0.46^{ns}	0.33^{ns}	0.64^{**}	-0.03^{ns}	0.73^{**}	-0.03^{ns}	-0.05^{ns}	0.38^{ns}	-0.24^{ns}	0.30^{ns}	-0.3^{ns}	0.02^{ns}	-0.01^{ns}	0.08^{ns}	0.05^{ns}	0.10^{ns}	0.06^{ns}	0.02^{ns}	1			
Na (mg/l)	-0.32^{ns}	0.33^{ns}	0.84^{**}	0.52^{*}	0.26^{ns}	0.87^{**}	0.27^{ns}	0.47^{*}	0.53^{*}	0.12^{ns}	0.66^{**}	-0.36^{ns}	0.04^{ns}	-0.08^{ns}	0.35^{ns}	0.07^{ns}	0.33^{ns}	-0.11^{ns}	-0.70^{**}	0.44^{ns}	1		
Mg (mg/l)	-0.15^{ns}	0.46^{ns}	0.55^{*}	0.50^{*}	0.001^{ns}	0.66^{**}	0.44^{ns}	0.10^{ns}	0.35^{ns}	0.12^{ns}	0.42^{ns}	-0.24^{ns}	0.11^{ns}	0.11^{ns}	0.11^{ns}	-0.37^{ns}	-0.16^{ns}	0.04^{ns}	-0.15^{ns}	0.68^{**}	0.51^{*}	1	
Ca (mg/l)	0.52^{*}	-0.25^{ns}	0.27^{ns}	-0.23^{ns}	-0.11^{ns}	-0.21^{ns}	0.23^{ns}	0.27^{ns}	-0.05^{ns}	0.57^{*}	0.13^{ns}	-0.01^{ns}	-0.03^{ns}	-0.01^{ns}	0.51^{ns}	-0.19^{ns}	-0.24^{ns}	-0.34^{ns}	-0.40^{ns}	-0.50^{*}	0.06^{ns}	-0.08^{ns}	1
Deter (mg/l)	-0.1^{2ns}	-0.13^{ns}	-0.03^{ns}	0.06^{ns}	0.17^{ns}	0.06^{ns}	-0.34^{ns}	0.03^{ns}	0.13^{ns}	0.06^{ns}	-0.13^{ns}	0.52^{**}	-0.21^{ns}	-0.24^{ns}	0.01^{ns}	0.10^{ns}	0.34^{ns}	-0.40^{ns}	-0.06^{ns}	0.32^{ns}	-0.06^{ns}	-0.06^{ns}	-0.10^{ns}

IRWQI for conventional and toxic pollutants

A total of 10 qualitative variables and three toxic variables were used to calculate these indices. Qualitative variables including BOD, COD, DO, EC, fecal coliform, sodium adsorption ratio (SAR), NO_3^-, TP, total hardness, and pH and toxic variables including detergent, Pb, and Fe were assessed. Table 5 presents different classes of groundwater quality index for conventional and toxic pollutants. The interpolation maps of the groundwater quality index (Fig. 2 to 5) indicate that in the summer of 2014, most of the districts were considered to be in bad and medium conditions, but in the winter of the same year, the condition changed to medium and relatively good. In the summer of 2016, most of the districts were in medium and fairly good condition, and in the winter of this year, the condition improved and most of the districts were on the relatively good class. In general, it can be concluded that the groundwater in the district 10 of Tehran had better conditions in terms of conventional pollutants in 2016 than in 2014. The water quality index for toxic pollutants in the mentioned seasons and years was on good and very good levels, indicating that the groundwater was not polluted by the toxic variables used to determine the index. Nejatijahromi et al. (2018) reported that the groundwater in Varamin was not polluted but the risk of groundwater contamination by heavy metals continues due to the persistence of contamination sources in the Varamin plain. As the maps show (Fig 2 to 5), the northern parts of district 10 had better conditions than the southern parts. The gentle slope extending from north to south of the district was probably the main reason for the bad conditions in the south than the north. Shirani et al. (2014) also expressed similar results regarding the accumulation of pollutants at the south due to the slope of their study area.

Table 4. Underground water quality index classes for conventional and toxic pollutants

<15	15-29.9	30-44.9	45-55	55.1-70	70.1-85	>85
Extremely Poor	Poor	Relatively Poor	Average	Relatively Good	Good	Extremely Good

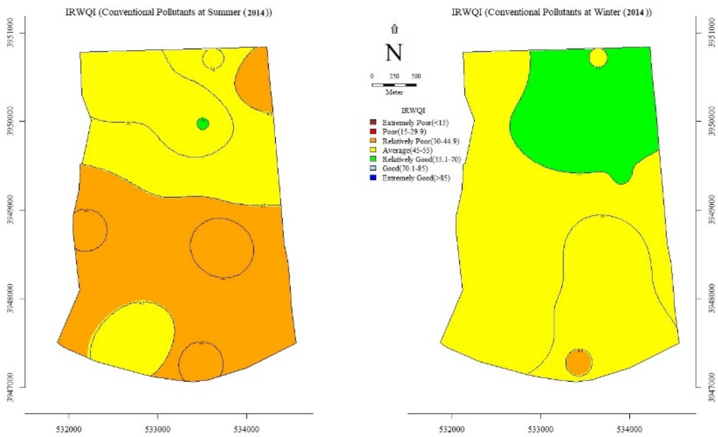

Fig. 2- IRWQI for conventional pollutants in 2014

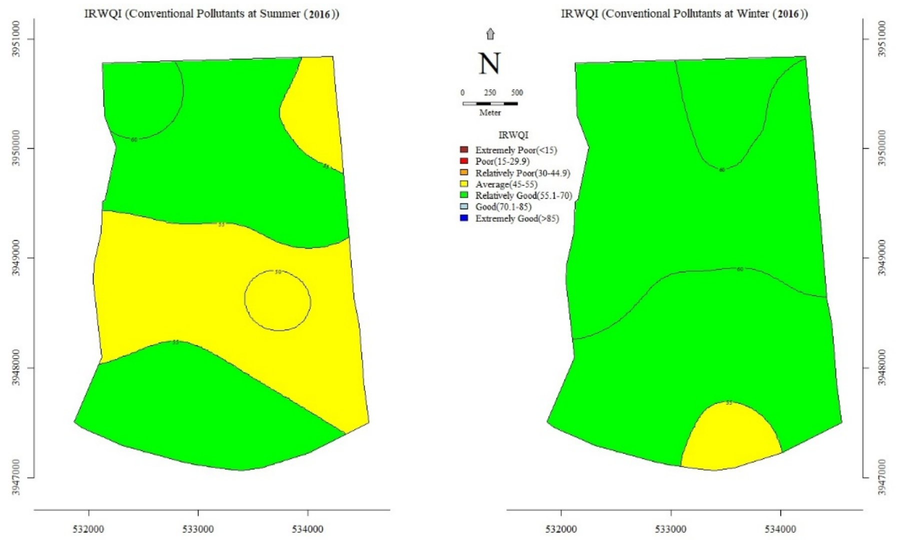

Fig. 3- IRWQI for conventional pollutants in 2016

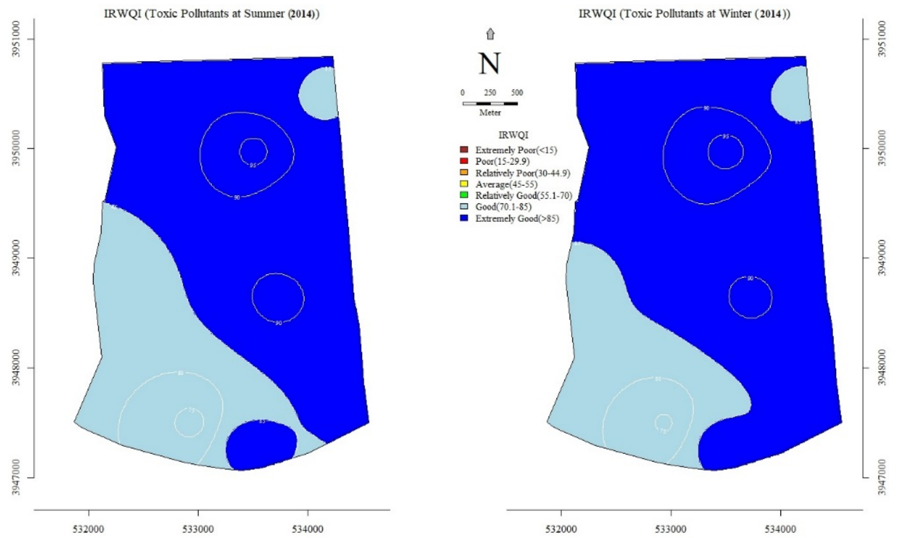

Fig. 4- IRWQI for toxic pollutants in 2014

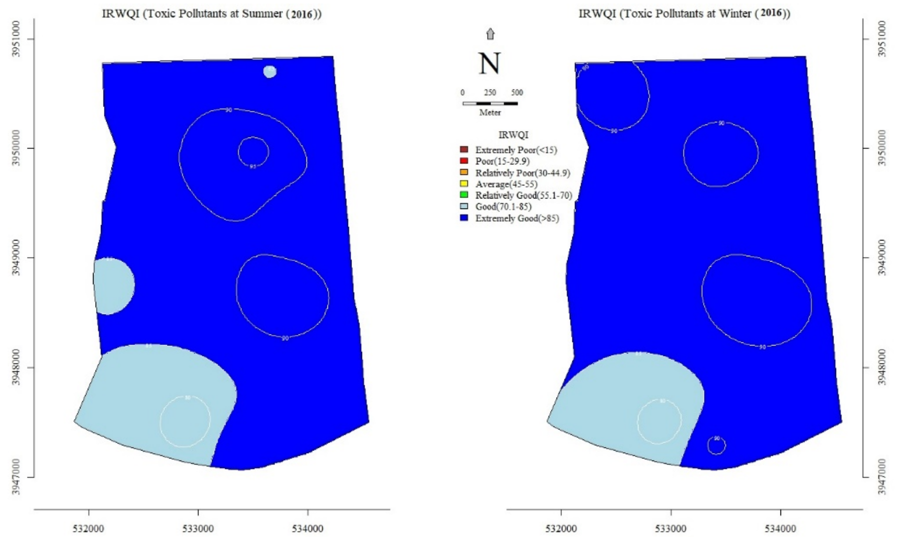

Fig. 5- IRWQI for toxic pollutants in 2016

Conclusion

The reported physicochemical and microbial data showed that the groundwater in district 10 had not serious problems and only the water turbidity violated the standard level. Conducting chlorine disinfection processes to eliminate coliform bacteria and treatment actions to reduce water turbidity seem to improve the water quality. While Shirani *et al*. (2013) reported the pH of water in district 14 of Tehran to be lower than neutral, the pH in this study was in the neutral to alkaline range. Considering the high concentration of NO_3^- and also the presence of coliform bacteria in the water, as well as the presence of detergent and the positive and significant correlation between detergents and water TP, it can be concluded that absorption wells have a considerable effect on the pollution of groundwater in the district. The data reported for heavy metals indicated the pollution of the groundwater with these metals. Although the water quality index was at a good level for toxic pollutants, some of the heavy metals measured in this study, which were not used in estimating this index, had a high concentration that indicates the effect of urban wastewater on groundwater. With rainfall and surface water flooding in the ward, toxic substances from fossil fuels are washed away from vehicles over time, and part of it will be transferred to the underground water with surface water (Hassanzadeh and Abbasnejad, 2016; Nejatijahromi *et al.,* 2018). These toxic substances will accumulate more in groundwater over time and, if consumed by humans, will cause poisoning. Furthermore, the depth of wells is another factors determining the concentration of metals in the groundwater, so that by reducing the depth of the well, the concentration of metals will also increase (Geen *et al.,* 2003). According to the data measured in the groundwater of this district, several factors can be mentioned as the source of groundwater pollution e.g. the use of chemical and animal fertilizers in the green spaces of the district, pollution due to human wastewater, and surface water flood entering the underground water.

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فصلنامه علوم محیطی، دوره هفدهم، شماره ۱، بهار ۱۳۹۸

۲۴۴-۲۲۹

بررسی کیفیت آب زیرزمینی منطقه ۱۰ تهران و مقایسه با استانداردهای ایران (INSO) و EPA برای استفاده شرب

فاطمه عفتی[1]، جواد بیات[2*]، مریم روحی‌کریق[3] و معصومه مولایی[4]

[1] گروه برنامه ریزی، مدیریت و آموزش محیط زیست، دانشکده محیط زیست، دانشگاه تهران، تهران، ایران

[2] گروه آلاینده‌های محیط زیست، پژوهشکده علوم محیطی، دانشگاه شهید بهشتی، تهران، ایران

[3] گروه محیط زیست، دانشکده کشاورزی و منابع طبیعی، دانشگاه صنعتی اصفهان، اصفهان، ایران

[4] گروه منابع طبیعی، بخش علوم و تحقیقات، دانشگاه آزاد اسلامی، تهران، ایران

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عفتی، ف.، ج. بیات، م. روحی کریق و م. مولایی. ۱۳۹۸. بررسی کیفیت آب زیرزمینی منطقه ۱۰ تهران و مقایسه با استانداردهای ایران (INSO) و EPA برای استفاده شرب. فصلنامه علوم محیطی. ۱۷(۱): ۲۶۸-۲۵۳.

سابقه و هدف: در سال‌های گذشته توسعه شهری، افزایش جمعیت و همچنین افزایش فعالیت‌های انسانی منجر به ایجاد مسائل و مشکلاتی در منابع آبی شهرها شده است. با توجه به افزایش نیاز به آب شرب در کلان شهرها، آگاهی از کیفیت آب مورد استفاده ضروری است.

مواد و روش‌ها: بدین منظور با هدف بررسی کیفیت آب زیرزمینی منطقه ۱۰ تهران، در سال‌های ۱۳۹۳ و ۱۳۹۵، در دو فصل تابستان و زمستان، تعداد ۹ چاه انتخاب شد و نمونه‌برداری از آنها انجام گرفت. متغیرهای مورد بررسی در این پژوهش شامل متغیرهای فیزیکوشیمیایی و میکروبی و هم چنین فلزات سنگین بود. متغیرهای فیزیکی مورد بررسی شامل دما، رنگ، کدورت، شوری و متغیرهای شیمیایی شامل pH، EC، TSS، TDS، نیتریت، نیترات، آمونیوم، فسفر کل، نیتروژن کل، سدیم، کلسیم، منیزیم، مس، آهن، سرب، کبالت، روی، دترجنت و متغیرهای میکروبی شامل کلیفرم گوارشی و کلیفرم کل است.

نتایج و بحث: نتایج نشان داد که بدلیل وجود باکتری‌های کلیفرم و همچنین میزان بالای نیترات، آب منطقه با فاضلاب انسانی یا حیوانی در تماس است ولی مشکل جدی وجود ندارد و با فرآیندی مانند ضد عفونی با کلر امکان بهبود کیفیت آب وجود دارد. از متغیرهای فیزیکی تنها کدورت آب از میزان استاندارد فراتر رفته و در برخی چاهها تا ۲ برابر میزان استاندارد گزارش شده است. نتایج مربوط به فلزهای سنگین نشان داد که غلظت فلزهای سرب، روی، آهن و مس در آب منطقه بشدت بالاست و چندین برابر میزان استاندارد گزارش شده که در صورت مصرف توسط شهروندان، اثرهای‌زیان باری بر سلامت آنها خواهند داشت. تغییرپذیری‌های فسفر کل نیز بسیار بالاست و تا ۰/۲۱ میلی‌گرم نیز گزارش شده است. میزان کلیفرم کل و کلیفرم گوارشی اگرچه پایین است ولی از استاندارد EPA برای آب آشامیدنی تخطی داشته که وجود این دو متغیر در آب زیرزمینی نشان دهنده ورود فاضلاب انسانی یا حیوانی به آب زیرزمینی منطقه بوده که در صورت مصرف سبب آسیب‌های جدی بر سلامت کودکان و افراد حساس خواهد شد. سختی کل نیز تغییرات زیادی ندارد ولی غلظت ۳۰۰ میلی‌گرم این متغیر

* Corresponding Author. *E-mail Address*: j.bayat194@gmail.com

مطلوب و ۶۰۰ میلی‌گرم نیز بیشترین سختی کل یک آب برای آشامیدن است که با توجه به میزان بیشینه این متغیر که ۳۹۰ میلی‌گرم گزارش شده، آب منطقه از نظر سختی نسبتا مطلوب بنظر می‌رسد. نقشه‌های پهنه‌بندی شده شاخص کیفیت آب زیرزمینی (شکل‌های ۲ تا ۵) نشان می‌دهد که در تابستان سال ۹۳ بیشتر نواحی منطقه از نظر آلاینده‌های متداول در شرایط بد و متوسط قرار دارد ولی در زمستان همین سال شرایط به سمت متوسط و کمابیش خوب تغییر کرده است. در سال ۹۵ در تابستان بیشتر منطقه در شرایط متوسط و به نسبت خوب قرار دارد و در زمستان همین سال شرایط بهتر شده و بیشتر منطقه در طبقه کمابیش خوب قرار گرفته است. شاخص کیفی آب برای آلاینده‌های سمی در هر دو فصل و هر دو سال، در طبقه خوب و بسیار خوب قرار دارد.

نتیجه‌گیری: داده‌های گزارش شده برای متغیرهای فیزیکوشیمیایی و میکروبی نشان داد که آب زیرزمینی منطقه از این نظر مشکل جدی ندارد و تنها کدورت آب از میزان استاندارد فراتر رفته است. بنظر می‌رسد که انجام فرآیند ضد عفونی با کلر برای از بین بردن باکتری‌های کلیفرم و عمل ترسیب برای کاهش کدورت آب، می‌تواند کیفت آب را بهبود بخشد. شاخص‌های محاسبه شده آب زیرزمینی برای آب منطقه نشان می‌دهد که بیشتر منطقه، از نظر آلاینده‌های متداول، در سال ۹۳ در رده بد تا متوسط قرار داشته در حالیکه در سال ۹۵ رده کیفیت به متوسط تا به نسبت خوب تغییر کرده است.

واژه‌های کلیدی: آب زیرزمینی، منطقه ۱۰ تهران، آلودگی آب، شاخص کیفیت آب.