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CASE STUDY

Environmental qualitative assessment of water resources in Tehran

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ABSTRACT: Increasing water demand and reducing its contaminations are the main concerns and challenges for water resource managers and planner due to its limited sources and high value. This study aims to assess and understand the factors which threaten the quality of groundwater resources and to achieve this, samples were taken from 14 active wells in District 3 of the Municipality of Tehran. After categorizing the parameters to distinct measurable groups containing anions (SO4, Cl, NO2, NO3, HCO3, CO3), cations (Mg, Na, k) heavy metals (Ag, Pb, Cd) physical parameters (temperature, color and odor) chemical parameters (Total Dissolved Solid , Electrical conductivity, Total Suspended Solids and pH, the data were analyzed using SPSS (version 16) software. The results revealed that excessive amount of nitrate anion in Paidari and Naji station is related to the slope and sandy texture of the wells and also the surrounding area's soil. Increased cation concentration was visible in Resalat well, which indicated the use of excessive amount of fertilizers containing sodium and also the clay soil texture. Cadmium was the only heavy metal with the concentrations of more than the standard amount. Domestic sewage and surface runoff and also regional geological structure, the lack of appropriate distance between water wells with sewage wells were among other reasons, causing underground water pollution.

KEYWORDS: *Chemical Parameters; Groundwater; Heavy metals; Physical parameters; Water demand; Wells*

INTRODOUCTION

Population growth and rising living standards in many countries result in the increase of demand for various uses of ground water for agricultural, industrial and urban usage (Sherbinin *et al*, 2007). Ground water as one of the most important water resources is facing various challenges, including natural and unnatural pollutants. Pollution is the introduction of a contamination into the environment (Comte *et al.*, 2016).

This could happen under the different activities that man engages in, that lead to pollution. The growth of human population, industrial and agricultural practices are the major causes of pollution (Eguabori, 1998). Pollution in water will certainly cause the water to become unusable. Thus, water pollution, in addition to damaging human health, also paralyzes socioeconomic development (Milovanovic, 2007). Awareness about water quality in each area could be helpful to maximize urban management programs in order to make optimal allocation of water (Booth and Lamble, 2012). Groundwater is the water that is located under the ground in the pore spaces in rocks and sediments under the surface of the earth. Originally are formed from rainfall or snow and then penetrates into the ground water system through the soil and in the long run either come to the surface (Zektser *et al.*, 2004).

- Quality calculation of water resources indicates that groundwater resources are accounted for about0.6%

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of the total available water resources (DEC, 2007). One of the greatest pressures on freshwater resources is the excessive amount of usage in agricultural irrigation (FAO, 2011). Agricultural water withdrawal accounts for 44% of total water withdrawal in OECD countries, and eight of these countries are very much dependent on groundwater for their agricultural uses (about 60%). In Brazil, Russian Federation, India and China, agriculture accounts for 74% of water withdrawals (this ranges from 20% in the Russian Federation to 87% in India). In the least developed countries, the fig. is more than 90% (FAO, 2011).

- Underground water resources in Iran and many other countries with similar climate, are used mostly for drinking water and agricultural uses (Mahdavi, 2004). Groundwater resources are constantly absorbing both natural and man-made pollutants which require implementation of environmental protection policies (Foster *et al*., 2002). In order to realize these goals, the possible contaminants and their sources have to be determined With the aim of effective water management, the European Union in 2000 adopted the Water Framework Directive (Directive 2000/60/EC) of the European Parliament and of the Council, establishing a framework for community action in the field of water policy (Cvitanic *et al.*, 2008). Numerous studies were conducted, investigating water quality, using different methods of sampling and analytical methods. Naseri and her colleagues, investigated the impact of natural and human factors in the quality of water resources in Lenjan plain in Esfehan. The samples were collected from 162 wells. The result showed high concentrations of major elements (Na, Ca, Cl). Moreover the results after applying statistical techniques (factor and cluster analysis) confirmed that the water-rock reactions in the aquifer environment indicate of human activities in the groundwater resources (Nassery *et al.*, 2012).

Masoudi and Barzegar (2015) paid special attention to assessment and zoning of qualitative and quantitative severity degradation of groundwater resources using the modified Iranian Model of Desertification Potential Assessment (IMDP) model and Geographic Information System (GIS) in the Firuzabad plain of Fars province. In this research, by using the decline indicator of underground electrical conductivity (EC), chlorine and Specific Absorption Rate (SAR) the severity of damage in the studied plain was evaluated. The results showed that the decline in groundwater level was approximately 93% of the plain's capacity, which indicates that the Firouzabad plain is in a state of extreme risk and in terms of quality status is about 36% of the standards which showed the moderate risk status. Hassanzadeh and his colleagues performed the groundwater pollution assessment in Kerman city in which, water quality of 43 wells were studied (Hassanzadeh *et al*., 2011). In their study, they have evaluated and compared 17 parameters with standard values. The results showed that the concentration of toxic elements such as lead, cadmium, chromium and manganese as well as some minerals such as sulfate and nitrate was higher than the permissible limit for drinking water (Hasanzadeh *et al*., 2011).

In another study, which took place in Borazjan plain the amount of chemical pollution in the ground water were investigated. The samples were collected from 12 wells. The result showed Chloride concentration of approximately 66% and SO_4 100%, Na 59%, NO3 42% were higher than the standard values (Mozafarizadeh and Sajadi, 2014). Shirani and colleagues worked on the groundwater resources, pollution assessment in Tehran. In this survey on 16 wells in District 14 of Tehran Municipality during 2011, they revealed that the increased chloride, sulfate, nitrate in the southern and western stations were associated with the slope of the northeast to the southwest as well as the sandy texture of the area. Increased cation concentrations in the wells of East and Northeast region, which were visible due to the increase of potassium, can be linked to the clay, wells, drainage of water and also the amount of fertilizer consumption in the green spaces. Cadmium was the only heavy metal that its concentration was exceeded from the standards (Sheirani *et al*., 2013).

In another study, heavy metals contamination of drinking water supplies in southeastern villages of Rafsanjan plain was examined. Using SPSS software (version 16), the result showed that the amounts of As, Pb and Cd, fail to meet basic standards of water quality in the studied area and the residents had been exposed to high levels of lead and cadmium (Malakootian and Khashi, 2017). Allouche and his colleagues paid attention to global risk approach to assessing groundwater vulnerability. This research provides a new approach to assess groundwater vulnerability to contamination from anthropogenic activities and seawater intrusion. The DRASTIC and GALDIT parametric methods were then linked to a novel land use index to create a more robust "global risk index", useful for assessing aquifer vulnerability to pollution and seawater intrusion risk. In addition, a sensitivity analysis was used to evaluate the effect of each individual parameter on the final models. The vulnerability to pollution and the seawater intrusion contamination maps show three classes of water resources degradation: low (25%), moderate (64%) and high (11%) depending on the hydrogeological characteristics, land use, distance from the coast and human impacts in most of the study area (Allouche *et* *al*., 2017). Career and Mali, performed their study with 54 samples with 12 variables (pollutants). The results of the factor analysis revealed that groundwater contains organic pollutants from three different sources. The analysis also showed considerable differences between the two sampling campaigns at individual sampling points. The results showed that the influence of pollution from various anthropogenic activities depends on the meteorological conditions in each sampling campaign (Cerar and Mali, 2016). Kannel and his colleagues examined the Spatial–temporal variation and comparative assessment of water qualities of an urban river system of the river Bagmati (Nepal). Seventeen stations were monitored for 23 physical and chemical parameters in winter seasons, for four consecutive years. The water quality measurement in the study period showed that the DO was below 4 mg/l and BOD, COD, TIN, TP and TSS above 39.1, 59.2, 10.1, 0.84 and 199 mg/l, respectively, in the urban areas. In the rural areas, DO was above 6.2 mg/l and BOD, COD, TIN, TP and TSS below 15.9, 31, 5.24, 0.41 and 134.5 mg/l, respectively. The analysis of data from 1988 to 2003 at a key station in the river revealed that the BOD was increasing in the Bagmati River (Kannel *et al*., 2007).

The objective of this research was to assess the quality of main water resources in District 3 of Tehran Municipality. The extent of contamination and its penetration into the ground aquifers, was enough encouragement to investigate the causes of the pollution. The limitation of the study was the lack of water quality data as well as lack of knowledge about the potential impact of natural and anthropogenic pollutants on the environment and on water quality. The research was carried out during the summer period in 2013.

MATERIALS AND METHODS

Case Study

Tehran is divided into 22 districts in terms of administrative division. Districts 3, as a part of the old Shemiranat zone, is located in the Northeast of the city of Tehran and geographically it is located A) Northern range: Chamran Highway, Modares Highway and Sadr Highway B) The east range: Pasdaranstreets and Shariati street C) the South range: Resalat Highway, Haqqani highway and Hemat highway. D) Western range: Chamranhighway. This district is adjacent with district 1from north, District 4 from east, District 2 from west and District 6 and 7 from south (Fig. 1). District 3 has 6 areas and 12 neighborhoods. According to preliminary data General Population and Housing Census 2011 population in region 3, is equal to 314112 people (Statistical Center of Iran, 2011-2012). During the period of formation of this district has less demographic growth than neighboring districts.

The population annual growth of this district since1980 in 2006 had been, approximately 1.13 percent and as the result of population expansion water quality can be affected by a wide range of human and also natural influences. Organic loading (e.g. sewage), pathogens, including viruses in waste streams from humans and domesticated animals, agricultural runoff and human wastes loaded with nutrients (e.g. Nitrates and phosphates) that give rise to eutrophication and oxygen stress in waterways, salinization from irrigation and water diversions, heavy metals, synthetic and persistent engineered chemicals (e.g. Pesticides), medical drug residues and hormone and their by-products, radioactive pollution, and even thermal pollution from industrial cooling and reservoir operations. After preliminary investigations about the wells in this district, number and the location of wells in the district were geographically determinedon the map. These 14 located wells are being used for irrigation of green spaces in the District 3. Fig. 2 shows the distribution of wells. Geographical location of the wells is also listed in Table 1.

For the sampling of the wells, 1.5 liter polyethylene containers were used. Two samples were taken from each 14 wells. In order to measure the concentration of heavy metals, one of the two samples was acidified with pure nitric acid to the pH of less than 2. For measuring the concentration of trace elements, graphite furnace atomic absorption method, and for the concentration of anions, titration and potentiometer (15), and for the concentration of cations (Mg, by using titration and Na, K, by flame Survey) took place. The device Specifications are listed in Table 2.

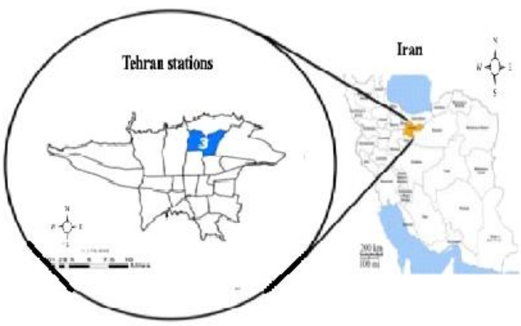

Fig. 1: Location of the study area with respect to 22 Districts of Tehran Municipality

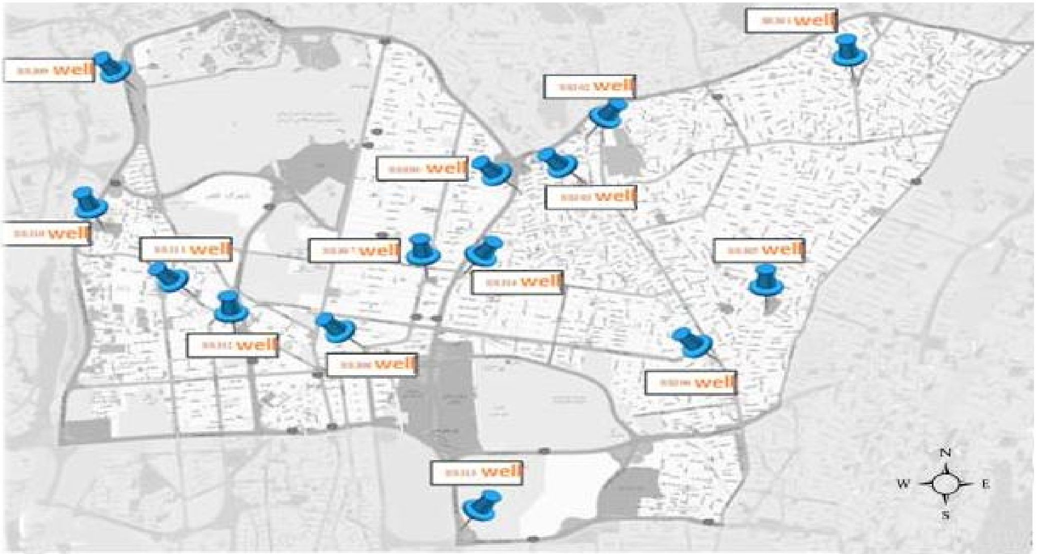

Fig. 2: Location of under study Wells in District 3

Table 1: Geographical location of the wells in the studied area

Row	Name of wells	Station's ID	Longitude coordinates	Latitude coordinates	Sampling
1	Arghavan well	SS301	3960356	541502	Park area
2	Fakhar well	SS302	3959639	539293	Park area
3	Zargandeh well	SS303	3959196	539295	Park area
4	Akhtar well	SS304	3959112	533741	Park area
5	Paidari well	SS305	3957868	540793	Park area
6	Shariati well	SS306	3957335	540364	Faucet
7	Saba well	SS307	3958102	537972	Park area
8	Khashayar well	SS308	3957413	537477	Park area
9	Bahareh well	SS309	3950976	536063	Park area
10	Mokhtari well	SS310	3958736	535387	Park area
11	Aftab well	SS311	3953013	536055	Park area
12	Seoul well	SS312	3957630	536386	Park area
13	Resalat well	SS313	3955415	533272	Inside Watercourse
14	Naji watercourse	SS314	3958166	538223	Inside Watercourse

Table 2: Specifications of the device used

Row	Device name	Model	Application
1	Graphite furnace atomic absorption	Varian 220 SpectrAA	Determination of heavy metals
2	Flame survey method	Flame photometer	Determination of K-Na
3	Potentiometric	Met Rohm 692- Ion meter	Measuring nitrate and sulfate anions
4	pH portable	WTW pH 330 I	Measuring the pH and temperature of the water in situ
5	EC portable	WTW Cond315 i	To measure the electrical conductivity in situ

RESULTS AND DISCUSSION

Sixteen parameters were evaluated from 14 wells in the District 3 of Tehran Municipality and after comparison of the results with the relating standards such as Chemical parameters and the concentrations of anions with the Food and Agriculture Organization legal standards for water quality of agricultural irrigation and also interpretive guidance on water quality of irrigation derived from the advisory committee of university of California in 1974 and the guidelines of concentrations of cations and heavy metals of Australian Water Quality Guide (Ground Water Resource Mapping in Ohio, 2011), it is revealed that most of the parameters in the samples taken from the wells were suitable for irrigation of green spaces within the city and are classified as average in the Wilcox table (Wilcox, 1948).

The parameters were divided into two categories: physical and chemical, the physical parameters including temperature, color and odor and chemical parameters (Total Dissolved Solid, Electrical conductivity, Total Suspended Solids and pH). Statistical analysis were performed using SPSS software (version 16).Temperature values were taken at the stations shown in Fig. 3. The highest temperature was from Paidari station and the lowest temperature was from Mokhtari station. The main reason for the high degree of water temperature is the sampling time which took place during the daytime (8 A.M. To 4 P.M.). The comparison of the temperature value in the stations is shown in Fig. 3.

The Minimum, the maximum and the average sum of chemical parameters presented in the under study groundwater, are shown in Table 3.

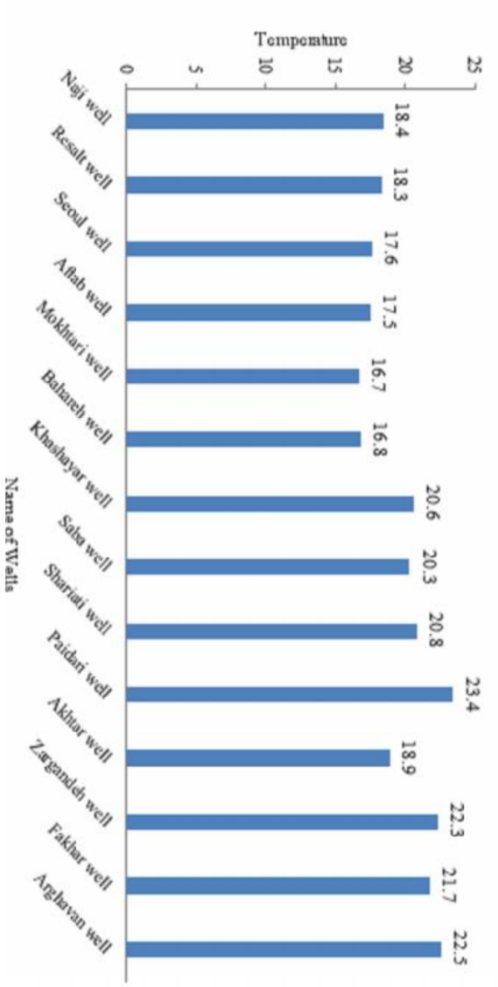

Fig. 3: Comparison of temperature value in the stations

According to the Fig. 4, the amount of pH value of water was in the range of 7, that means no restrictions for irrigation use in the green spaces.

The concentration of total dissolved solids (TDS) is related to the electrical conductivity (EC). The analysis results of water samples using SPSS software were reviewed and the electrical conductivity showed that, except Resalat station with the highest EC, the water conditions in other wells were suitable for irrigation (Fig. 5). Concentrations below 5 mg per liter except for Saba and paidari stations with the values of 6 and 16, considered zeroand negligible. The amount of this parameter is usually very small in the ground water unless the pipelines are made of cast iron, and steel therefore the average TDS of 7.01 mg/L is suitable with no restriction on using for irrigation (Fig. 6).

Table 3: The minimum and the maximum value of chemical parameters in the groundwater

Parameter analysis	TDS (mg/L)	TSS (mg/L)	EC (Ds/m)	pH
Average	7.01	47.85	1.001	7.41
Maximum	111	5	1593	7.97
Minimum	523	5	674	6.89
Middle	671	5	9/50	7.36
The maximum allowance for chemical parameters for agriculture (Ayers and Westoct, 1985)	2000	-	2700	6 to 8.5

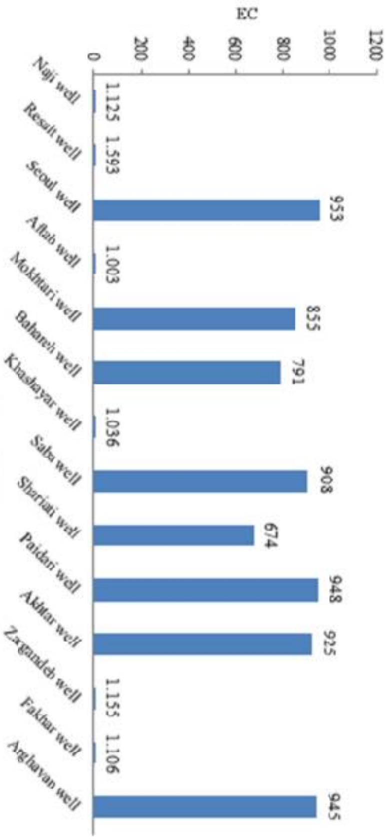

Fig. 5: Comparison of EC value in the stations

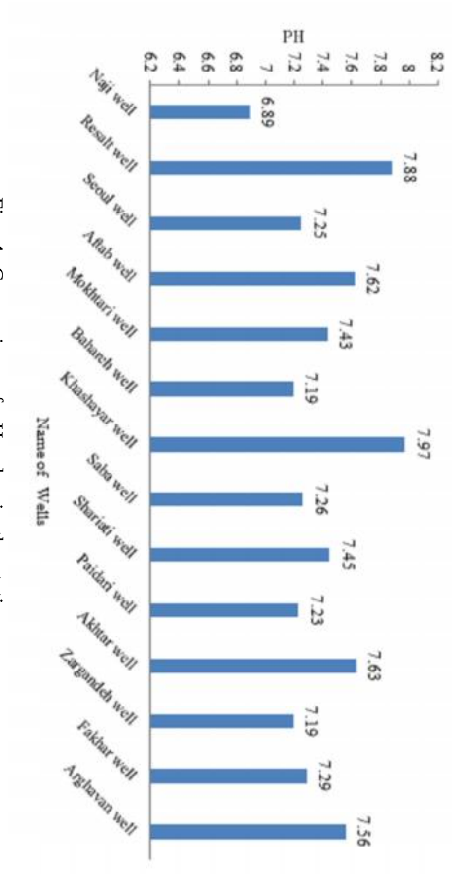

Fig. 4. Comparison of pH value in the stations

Resalat station was the only well with high levels of soluble salts which failed the agricultural standard and its water was categorized as brackish water. This amount of soluble salts is due to the location of this station at the southernmost point of the area (Fig. 7).

The amount of nitrate concentration was the only anion which was higher than the maximum standard in Paidari and Naji stations and the amount of sodium concentration was more than the standard limitation from the group of understudied cations. The results also showed that the Nitrite concentration in Najiand Paidari wells were higher than other wells (Fig. 8).

Tables 4 and 5 indicate that among the anions parameters, nitrite concentration was the only anion which was higher than the maximum standard and among the cation parameters, the sodium element concentration, according to the results obtained, in Resalat station was higher than the allowed standard therefore, the Specific Absorption Rate (SAR) must be calculated in order to be defined for suitability for irrigation.

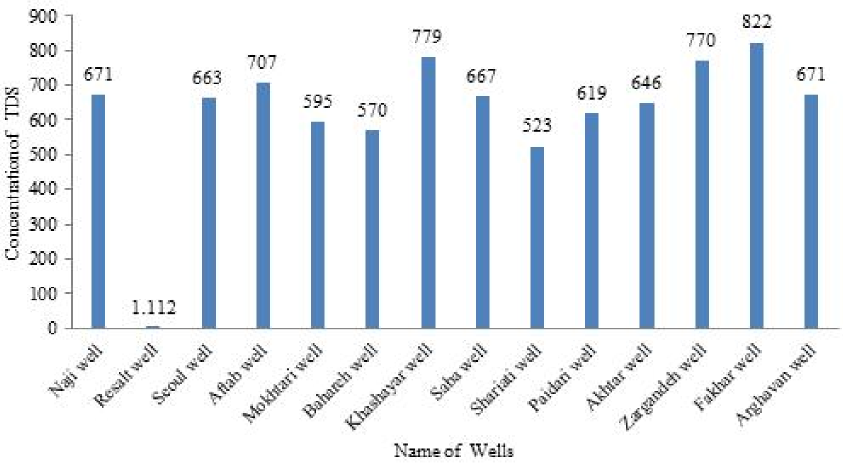

Fig. 6: Comparison of TDS value in the stations

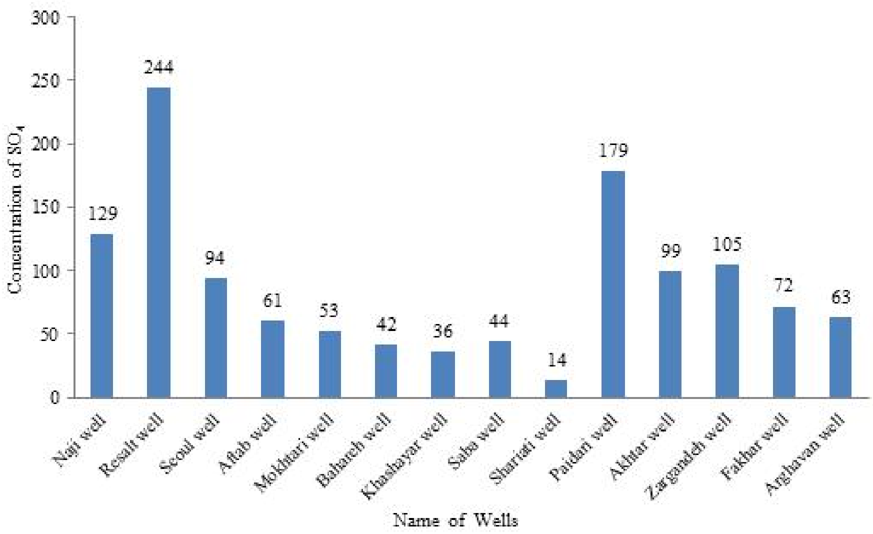

Fig. 7: Comparison of SO_4 value in the stations

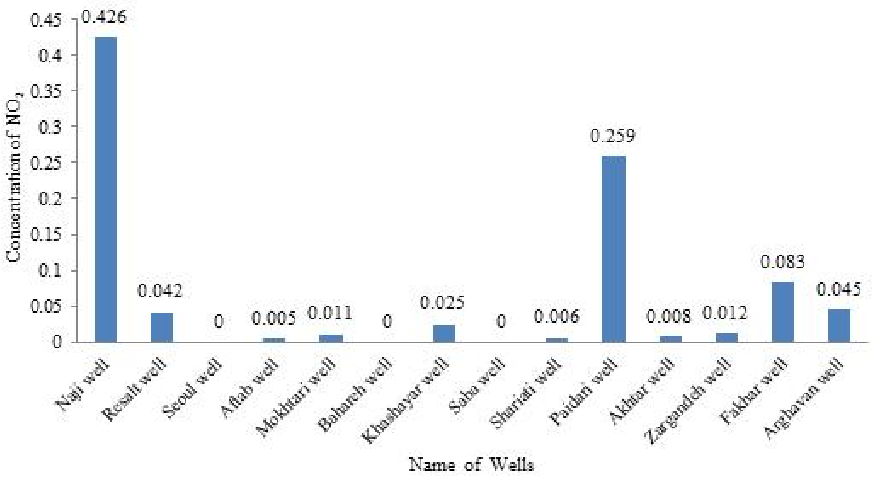

Fig. 8: Comparison of NO2 value in the stations

Table 4: The minimum, maximum and the average value of anion parameters of ground water

Parameter analysis	CL^-(mg/L)	HCO_3^- (mg/L)	CO_3^{-2} (mg/L)	SO_4 (mg/L)	NO_2^- (mg/L)	NO_3^-(mg/L)
Average	1.11	276.1	0	88.21	0.65	6.86
Maximum	214	403	0	244.00	0.42	16.60
Minimum	56	0	0	14.00	0.00	1.50
Middle	90	268	0	14.00	0.00	1.50
Maximum allowable for agriculture (Ayers and westoct, 1994)	500	600	.	950	.	600

Table 5: The minimum, maximum value cations parameters of groundwater area

Parameter analysis	Mg (mg/L)	K(mg/L)	Na (mg/L)
Average	20.28	3.59	93.21
Maximum	27.9	8.90	286.0
Minimum	0.00	1.60	20.00
Middle	27.9	1.60	70.00
The maximum allowable for agriculture(Ayers and Westoct, 1985)	60.00	75.00	900.0

Among the measured heavy metals, Cadmium concentration was higher than the standard range and other heavy metals such as Silver and Lead had no restriction for irrigation use in the green spaces and the parks. In Table 6, the concentration of heavy metals in the groundwater area and their comparison with international standards are shown.

The obtained result also showed that the amount of NO_3 in Naji, Zargande and Paidari wells, respectively, were higher than the other wells (Fig. 9).

Except in Paidari and Saba stations, the amount of TSS in all the wells was 5 mg per liter which was even less than the standard. The cause of the proliferation of TSS may be related to the use of cast iron and steel pipes in the water transmission lines. Presence of suspended solids which are consisted of carbonate, bicarbonate, chloride, phosphate and other solid materials were due to the areas with concentration of waste discharge, which sometimes this factor is considered as an indicator of pollution in the district.

The concentrations of Chloride in the Naji station were higher than the other stations (Fig. 10). The sulfate was the most important sulfur compound that is found naturally in water. The concentration of sulfate ion in the Paidari and Resalat stations was higher than other stations and shariati station had the lowest sulfate ion concentration. The increase of sulfate can be related to the atmospheric acid and also the fertilizers which normally are penetrated with rainwater into the soil and underground water.

As bicarbonate ion causes the calcium and magnesium absorbed slightly into the soil, it is counted as an important parameter for measuring the quality of irrigation water. The amount of Specific absorption rate (SAR) parameter was variedin 14 stations due to the increase of the sedimentation and did not follow a specific pattern. The important point was the very low level of bicarbonate in Paidari station. Although the presence of carbon sediment is common in surface water, but this factor is more severe in underground water. The bicarbonate ion has been diagnosed next to zero in all the wells.

Table 6: The comparison of heavy metal concentration in the groundwater area with international standards

	Pb (mg/L)	Cd (mg/L)	Ag (mg/L)
All wells	5>	>1	1>
Standard Level	5	1	1

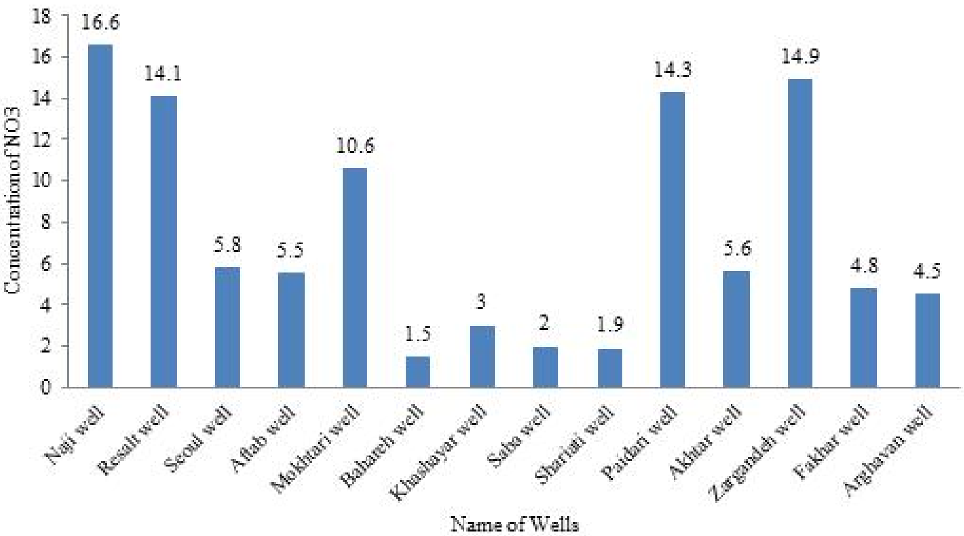

Fig. 9: Comparison of NO_3^- value in the stations

Analysis of underground water and comparison of potassium concentration with the international standards of quality of agricultural water proved that the amount of this element in Resalat and Naji wells was higher than other stations and noticeably higher than the standards (Fig.11).

It can be comprehended that according to the alluvium map of Tehran, this area is formed of fine-grained sediments (silt and clay) and the potassium is in the mineral matter such as feldspar, mica, clay. Thus the increasing potassium in this area is due to the structure of this area. The amount of magnesium in the ground water was less than standard, but the increasing of the relative concentration in some parts of this area is due to the to the geologic structure of the district.

The results of heavy metals concentrations which were compared with the irrigation water standards showed that the concentration of heavy metals except of cadmium in Naji station were lower than the permissible limit. Therefore the sources of the irrigation water from the wells from the heavy metals view point are reliable to use for different purposes. So it can be concluded that for so many reasons such as limited number of industries, geological composition, reduction of the influence of urban sewage into the water resources, geographic and environmental conditions this district is not exposed to heavy metals contamination (except cadmium).

High level of Cadmium concentration in all the studied wells indicates that the flow of rain water surface runoff and their penetration into the underground water along with the present contamination in the soil must be the cause of this pollution. In a study by Karbasi and his colleagues on the concentration of heavy metals in the drinking water

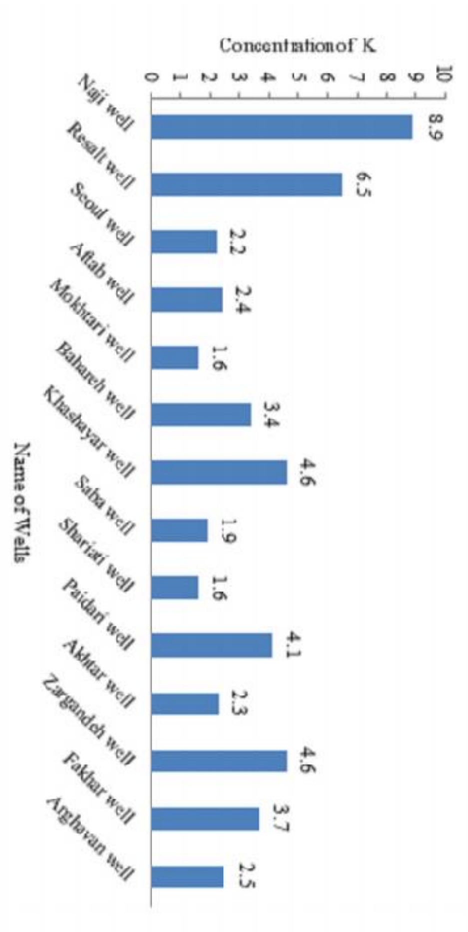

Fig. 11: Comparison of K value in the stations

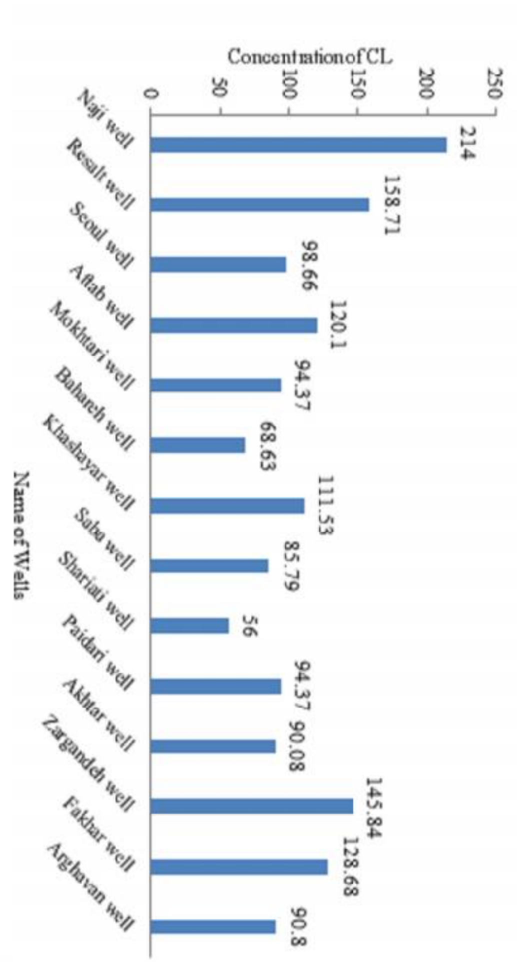

Fig. 10: Comparison of CL⁻ value in the stations

resources in Elshter province, the results showed that the concentration of mercury, cadmium, arsenic, lead and chromium in none of the samples were exceeded the related national standard (Karbasi *et al*., 2010).

Saeedi and his colleagues also proved, in their study, that the concentration of Cadmium, Copper, Lead and Nickel were not different from the permitted average amount of heavy metals except of Iron which was slightly higher in the studied area of Tajan river water in Mazandaran (Saeedi *et al*., 2007).

CONCLUSION

Generally, District 3 is divided into 6 regions; in this study the quality of underground water area was examined. The studied parameters were chemical, physical, anions and cations. By comparing the concentration of chemical elements in different wells, it was found that Naji and Paidari wells in region 4 and 5 had the most contaminations, which is the main factor in the increase of soluble materials and also increase of electrical conductivity. Relating to the concentration of total anions, most of the anion pollution, such as nitrite which was mostly found in the region 4 and 5, areassociated with increased human population in these areas and existence of green spaces which in turn leads to increase consumption of fertilizers and increase of sewage production.

According to the high solubility of Nitrate and no specific process for its deposition, Nitrate is transferred towards groundwater gradient and its concentration in the end zone remains almost constant. The results showed that concentrations of Chloride and Sulfate in groundwater are lower than the limited amount. Thus, it can be concluded that the consumption of well’s water for irrigation in the region is without serious problems. The average concentration of ground water pollution indicates that there were no traces of heavy metals such as Lead and Silver (except for Cadmium) which indicates the suitability of the ground water for irrigation use.

This research paper has revealed that the use of chemical fertilizers in urban green spaces, parks and gardens in the District 3 is influenced by several factors. Lack of sanitary disposal network and sewage treatment system for treating the runoff water and sewage which in turn would result in penetration of surface water along with the significant amount the soluble salt to the underground layers and finally entering and mixing with the groundwater resources. Moreover topographical and the Geological condition of the study area, the lack of proper spacing between water wells and sewage in some areas and also the shallow depth of the wells are the main causes of the contamination of groundwater and the wells in District 3 of Tehran Municipality.

Suggestions:

1. Using different methods of improved irrigation such as sprinkler irrigation or drip irrigation
2. Perform periodic testing of the soil to determine the actual needs of soil fertilizers
3. Distribution of permissible and standard fertilizers for the urban green spaces
4. Using the relevant legal standards and if not available, setting national and provincial standard
5. Use of environmentally friendly fertilizers

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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