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Physico-chemical Analysis of Drinking Groundwater of Around Tehran by Seasonal Variation

[1]F. Pourfallah, [1]S. Javadian, [1]Z. Zamani, [2]S.D. Siadat, [1]Sh-Khatami, [1]R. Saghiri and [3]T. Kordi
[1]Departement of Biochemistry, Pasteur Institute of Iran, Tehran, Iran
[2]Department of Microbiology, Pasteur Institute of Iran, Tehran, Iran
[3]University of Tehran, Tehran, Iran

Abstract: This study was a cross-sectional descriptive study and done in four seasons during April 2011 to March 2012. The objective of the present study was to examine Physico-chemical properties of groundwater around Tehran. The results are also compared with the guideline values of Iranian legislation. A total of 160 drinking water samples were collected from different drinking groundwater around the Tehran. Total Dissolved Solids (TDS), conductivity and pH, were measured by using standard methods and the concentration of ions Cl^-, F^-, NO_3^-, NO_2^-, Br^-, SO_4^{2-}, PO_4^{3-}, Ca^{2+}, K^+, Na^+ and NH_4^+ in groundwater was performed using Ion chromatography (Metrohm Company, USA) with standard method. This study showed that most of the parameters in groundwater were below the Iranian permissible limit except total dissolved solids (N = 2), conductivity (N = 2), nitrate as NO_3^- (N = 22), chloride (N = 3), sulphate (N = 2), fluoride (N = 3) and ammonia (N = 8). There were significant differences (p<0.05) between physico-chemical parameters such as pH, nitrite (NO_2^-), sodium, potassium, sulphate, ammonia, bromide and phosphate in different seasons. These results are important, not only for the many people who drink groundwater but also for the health supervisory agencies such as Ministry of Health and Institute of Standards and Industrial of Iran (ISIRI) to have more effective control on groundwater.

Key words: Groundwater, physico-chemical, seasonal variation

INTRODUCTION

Water is one of the most important substances on earth. The demand of water is expected to increase in the next few years while the ability to develop new water resources has been declined (Lucie, 2004).

Human health may be directly affected by Water and one of the main categories of health risks can be associated with chemical pollutants. Potential contamination problems can reach a well which is a mile away, through water flowing underground (Zaporozec *et al.*, 2002). Once groundwater is contaminated, the operation of removing the contamination is very costly; as a result the quality and quantity of groundwater resources must be monitored constantly (American Water Works Association, 1999).

The water demand in Iran is supplied by surface and underground water sources. Groundwater resources provide satisfactorily more than the half of the total annual water demand in Iran. Tehran Province is one of the 31 provinces of Iran. It covers an area of 18,909 square kilometers and is located in the north central plateau of Iran (Farhang *et al.*, 2011).

The objective of the present study was to examine groundwater around Tehran in different seasons for Total Dissolved Solids (TDS), conductivity, pH, nitrite (NO_2^-), nitrate (NO_3^-), calcium, chloride, sulphate, potassium, fluoride, ammonia, bromide and phosphate. The results were also compared with the guideline values of Iranian legislation.

MATERIALS AND METHODS

A total of 160 water samples were randomly collected from groundwater around Tehran, the capital of Iran, is done in four seasons during April 2011 to March 2012. Sampling from different drinking groundwater was carried out during 4 seasons: spring, summer, autumn and winter. For physico-chemical examination, the groundwater samples were taken after flushing water for at least 5 min. Sampling in each site was replicated 3 to 4 times and the mean value was presented. The samples were sent for laboratory analysis to Pasteur Institute. The samples were collected in polythene containers and moved to laboratory and were immediately analyzed. Sampling methods and analytical procedures were done according to standard methods for the examination of water and wastewater (APHA, 2005).

pH was measured, using pH-meter (Metrohm instrument model 827), after calibration with standard pH buffers. EC was determined by conductivity meter (Trans), after calibration with standard solutions. For TDS

Corresponding Author: S. Javadian, Department of Biochemistry, Pasteur Institute of Iran, Tehran, Iran

(total dissolved solids), the water sample was filtered through Whatman No 4 and then evaporated the sample on hot water bath until all the water evaporated. After cooling, the weight of evaporating dish and calculated total dissolved solids were measured (APHA, 2005).

The concentration of ions Cl^-, F^-, NO_3^-, NO_2^-, Br^-, SO_4^{2-}, PO_4^{3-}, Ca^{2+}, K^+, Na^+ and NH_4^+ in groundwater was determined by Dionex ICS-1000 from USA. The mobile phase for anionic measurement was 1.3 mM Na_2CO_3 +2 mM $NaHCO_3$ and for cationic measurement was 4 mM of Tar Taric acid +0.75 mM Dipicolinic. Calibration standards of appropriate concentration were prepared on a daily basis by diluting IC Multielement standard (Fluka 89316 and 89886).The calibration curve had to be verified on each working day, whenever the anion eluent changed. All solutions were prepared in HPLC grade deionized water and were filtered before analysis. Water samples were measured directly with no pretreatment other than being filtered a 0.45 µm filter (Jackson *et al.*, 1999).

All statistical analyses were performed using the software SPSS package (Windows version 13SPSS, Chiago, III., USA). The results were analyzed by Kolmogorov-Smirnov test for evaluation of normal distribution of data, one way Anova for the comparison of data among seasons. The mean and Standard Deviation (SD) were used for reporting and a p-value of <0.05 was considered statistically significant.

RESULTS AND DISCUSSION

The respective values for all these Physico-chemical parameters by seasonal variation are reported in Table 1. All results are compared with standard limits recommended by the guide line value of Iranian legislation in Table 2.

pH values: The pH values for all samples varied from 6.90 to 8.37. Overall mean pH was 7.67±0.25 in all investigated water samples (Table 1). The pH shows slightly alkaline trend. The limit of pH value for drinking water according to Iranian legislation is specified as 6.5 to 8.5 (ISIRI, 1997). There was a significant difference (p<0.05) between pH and seasons (Table 1).

Electrical conductivity: The electrical conductivity results of water samples showed a large variation which ranged from 200 to 2300 µS cm^{-1} (Table 1). The limit of EC for drinking water according to Iranian legislation is up to 2000 µS/cm (ISIRI, 1997). Most samples were within the

Iranian legislation limit for water. Only two water samples reported the EC value were out of Iranian legislation range (Table 2).

Total dissolved solids (TDS): The TDS values of samples varied between 65 and 1495 mg L^{-1} (Table 1). These values were within the Iranian legislation (ISIRI, 1997).

Chloride: The overall mean value of chloride content in all drinking water samples was 83.57±84.5 mg L^{-1} The range of chloride determined in samples was between 1.604 and 479.7 mg L^{-1}; however, in spring, the range of chloride determined in samples was between 5.31 and 159.6 mg L^{-1}, less than the other seasons (Table 1). The standard value for chloride is 400 based on the Iranian National Legislation guideline (ISIRI, 1997). The limits of chloride have been laid down primarily from taste considerations. However, no adverse health effects on humans have been reported from the intake of waters containing even higher content of chloride (Jim, 2005).

Ammonia: The ammonia values for all samples varied from 0.126 to 5.632 mg L^{-1} (Table 1). The Iranian permissible limit of ammonia in water is 400 mg L^{-1} (ISIRI, 1997), but it is less than 250 mg L^{-1} based on the WHO guideline (WHO, 2006). The Maximum range of Ammonia was detected in autumn (Table 1). There was a significant difference (p<0.05) between ammonia and seasons (Table 1). Ammonia enters water from fertilizer runoff, leaching septic tanks and erosion of natural deposits (Makarovsky *et al.*, 2008).

Fluoride: It is presented in Table 1 that fluoride ions were found in all water samples at concentrations between 0.002 and 2.95 mg L^{-1}. Fluoride in well water may come from natural sources (Brindha *et al.*, 2011).

Nitrite and nitrates (NO_2^-, NO_3^-): The nitrite concentration in all water samples was below the minimum permissible limits (3 mg L$^-$ as NO_2^-) (Table 2). There was a significant difference (p<0.05) between nitrite and seasons (Table 1).

The overall mean value of nitrate (NO_3^-) content in all drinking water samples was 31.95±28.12 mg L^{-1}. The range of nitrate determined in samples was between 0.001 and 124.6 mg L^{-1} (Table 1) and 22 samples had nitrate (Table 2) above the permissible limit of nitrate (NO_3^-) in Iran (50 mg L^{-1}) (ISIRI, 1997).

Sulphates: The sulphate levels varied between 0.003 and 505 mg L^{-1}. Most of these concentrations were within the

Table 1: Physico-chemical constituent results of drinking groundwater samples around Tehran during April 2011 to March 2012

Water source/ Physico-chemical parameter	Spring (N = 40) Mean±SD	Range	Summer N = 40 Mean± SD	Range	Fall (N = 40) Mean±SD	Range	Winter (N = 40) Mean±SD	Range	Total (N = 160) Mean±SD	Range
pH	7.50±0.2^{cd}	6.90-7.9	7.6±0.17^{cd}	7.3-7.9	7.7±0.21^{ab}	7.27-8.20	7.7±0.22^{ab}	7.36-8.37	7.6±0.23	6.9-8.3
Conductivity (μS/cm)	210.0±115	150.0-400	220.0±153	120.0-900	347.0±302	220.0-2300	337.0±306	200.0-1600	278.1±235	150.0-2300
Total dissolved solid (mg L^{-1})	136.5±75.08	69.0-260	143.1±99.45	70.0-585	225.5±208.3	65.0-1495	219.0±190.2	68.0-1040	180.7±157.98	65.0-1495
Chloride (mg L^{-1})	66.62±36.4	5.31-159.69	91.15±55.80	10.34-402.2	94.82±61.84	1.60-479.7	80.17±53.47	10.32-392.09	83.5±49	1.6-479.7
Ammonia (mg L^{-1})	0.80±0.41^{cd}	0.30-1.58	0.99±0.54	0.12-2.84	1.2±0.45^{a}	0.157-5.6	1.2±0.63^{a}	0.14-3.49	1.08±0.70	0.12-5.6
Fluoride (mg L^{-1})	0.25±0.09^{c}	0.001-0.80	0.35±0.13	0.002-1.90	0.43±0.22^{a}	0.08-2.95	0.32±0.12	0.13-0.851	0.34±0.14	0.001-2.95
Nitrite (NO$_2^-$) (mg L^{-1})	0.26±0.09	0.003-0.912	0.28±0.1^{cd}	0.001-074	0.13±0.05^{b}	0.001-0.95	0.12±0.06^{b}	0.001-0.69	0.19±0.06	0.001-0.95
Nitrate (NO$_3^-$) (mg L^{-1})	29.59±20.85	0.002-73.25	37.25±25.11	30.11-79.99	28.10±22.16	0.001-119.80	32.51±22.41	2.69-124.62	31.95±25.12	0.001-124.62
Sulphate (mg L^{-1})	56.4±24.48^{d}	0.1-116.7	82.45±47.27^{c}	0.003-188.39	117.43±82.88^{ab}	12.86-353.7	90.3±75.7^{a}	30.26-505	87.46± 52.17	0.003-505
Sodium (mg L^{-1})	16.37±10.88^{c}	2.16-41.47	21.06±10.20^{c}	2.38-55.33	50.77±13.33^{abd}	2.29-272.18	22.57±16.1^{c}	0.007-56.340	28.44±19.09	0.007-272.18
Potassium (mg L^{-1})	0.50±0.058	0.006-0.22	0.112±0.04^{c}	0.01-1.22	1.14±0.52^{abd}	0.002-9.204	0.045±0.001^{c}	0.004-0.267	0.36±0.06	0.002-9.20
Calcium (mg L^{-1})	7.5±4.1600	0.27-49.55	7.6±5.03	0.01-39.55	5.03±3.8	0.01-58.67	4.5±2.7	0.898-34.79	6.19±3.84	0.001-58
Phosphate (mg L^{-1})	0.0057±0.002^{bd}	0.001-0.07	0.039±0.007^{cd}	0.001-0.40	0.002±0.0005^{bd}	0.001-0.26	0.04±0.006^{ac}	0.001-0.22	0.02±0.005	0.001-0.40
Bromide (mg L^{-1})	0.15±0.05^{b}	0.001-0.63	0.39±0.16^{acd}	0.03-0.98	0.091±0.04^{b}	0.001-0.62	0.07±0.03^{b}	0.001-0.29	0.18±0.02	0.001-0.98

[a]Variation against spring water samples (the mean difference is significant at p< 0.05 level), [b]Variation against summer water samples (the mean difference is significant at p<0.05 level), [c]Variation against autumn water samples (the mean difference is significant at p<0.05 level), [d]Variation against winter water samples (the mean difference is significant at p<0.05 level)

Table 2: Percentage of water samples exceeding the permissible limits of physic-chemical parameters of the examined drinking water sources

Water source/ Physico-chemical parameter	Permissible limit*	Spring (N = 40) Over permissible limit No.	%	Summer (N = 40) Over permissible limit No.	%	Fall (N = 40) Over permissible limit No.	%	Winter (N = 40) Over permissible limit No.	%
pH	6.5-8.5	0	0.0	0	0.0	0	0.0	0	0.0
Conductivity (μS/cm)	2000	0	0.0	0	0.0	2	5.0	0	0.0
Total dissolved solid (mg L^{-1})	1500	0	0.0	0	0.0	2	5.0	0	0.0
Chloride (mg L^{-1})	400	0	0.0	1	2.5	2	5.0	0	0.0
Ammonia (mg L^{-1})	1.5	1	2.5	2	5.0	3	7.5	2	5.0
Fluoride (mg L^{-1})	1.7	0	0.0	1	2.5	2	5.0	0	0.0
Nitrite (NO_2^-) (mg L^{-1})	3	0	0.0	0	0.0	0	0.0	0	0.0
Nitrate (NO_3^-) (mg L^{-1})	50	5	12.5	8	20.0	4	10.0	5	12.5
Sulphate (mg L^{-1})	400	0	0.0	0	0.0	0	0.0	2	5.0
Sodium (mg L^{-1})	200	0	0.0	0	0.0	0	0.0	0	0.0
Potassium (mg L^{-1})	---	0	0.0	0	0.0	0	0.0	0	0.0
Calcium (mg L^{-1})	250	0	0.0	0	0.0	0	0.0	0	0.0
Phosphate (mg L^{-1})	--	0	0.0	0	0.0	0	0.0	0	0.0
Bromide (mg L^{-1})	---	0	0.0	0	0.0	0	0.0	0	0.0

*: Iran standards for drinking water (MCL)

range of water standards of Iran (250 mg L^{-1}) (ISIRI, 1997). Five water samples showed the concentrations of sulphate greater than 250 mg L^{-1}. There was a significant difference ($p<0.05$) between sulphate and seasons (Table 1). Ingestion of water containing high levels of sulphate, may be associated with Diarrhoea and other gastrointestinal disorders (Backer, 2000).

Sodium: The sodium levels were from 0.007 to 272 mg L^{-1} (Table 1). Only two samples were out of the ranges of Iranian water standards (200 mg L^{-1}) (Table 2). There was a significant difference ($p<0.05$) between sodium and seasons (Table 1).

Potassium: The potassium levels varied between 0.002 and 9.24. There was a significant difference ($p<0.05$) between potassium and seasons (Table 1). The US EPA does not have any standards regarding the amount of potassium healthy to ingest in drinking water (U.S. EPA, 2008). Potassium comes from dissolving rock, fertilizer, salt and soil (Provin and Pitt, 2001).

Calcium: The Calcium levels varied between 0.001 to 58.67 mg L^{-1} (Table 1).The maximum range of calcium in Iran legislation is up to 250 mg L^{-1} (ISIRI, 1997) and all samples were in permissible limit (Table 1).

Phosphate: Phosphate of water samples showed short variation which ranged from 0.001 to 0.4 mg L^{-1}, (Table 1). There was a significant difference ($p<0.05$) between phosphate and seasons (Table 1). The US EPA does not have any standards regarding the amount of phosphate healthy to ingest in drinking water (U.S. EPA, 2008). Excessive consumption of phosphorus may lead to osteoporosis and poor bone maintenance. Several studies suggest that higher intakes of phosphorus are associated with an increased risk of cardiovascular disease (Health impacts and Water pollutants, 2012).

Bromide: The Bromide levels varied between 0.01 and 0.98 mg L^{-1} There was a significant difference ($p<0.05$) between bromide and seasons (Table 1). Chlorination of water that contains bromide ion may produce bromate ion (an undesirable disinfection by product) which is carcinogen and nephrotoxin. (Guidance for Water Suppliers, 2010).

CONCLUSION

In autumn five percent of samples were above the Iranian legislation permissible limit of EC and TDS. Eight of the samples reported the ammonium and two of samples reported the sulphate were out of the Iranian range (Table 2). It is presented from Table 2 that chloride in summer and autumn showed 2.5% and 5% respectively was above the Iranian permissible limit (Table 2).

Three samples had fluoride above Iranian permissible limit but on the other hand the results showed that in 130 samples fluoride concentrations were below the World Health Organization (WHO) minimum permissible limit (0.7 mg L^{-1}). It has been suggested that if the level of fluoride in drinking water is below 0.7 mg L^{-1}, supplements may be required in some cases, whereas, if the level is >0.7 mg L^{-1}, supplementation is not necessary (Fawell *et al.*, 2006). In that case, the authors suggested that fluoride supplementation should be considered because of the lack of optimal level of fluoride.

It was concluded that nitrate contents in groundwater sources for water supply in Tehran were higher than standard level (N = 22) .The public health must concern

for people who consume contaminated water. Because nitrate is colorless, tasteless and odourless, water must be chemically tested to determine the amount of nitrate level in wells accurately (Lake *et al.*, 2003).

All the remaining Physico-chemical parameters such as pH, Br^-, SO_4^{2-}, PO_4^{3-}, Ca^{2+}, K^+ and Na^+ were below the permissible limits prescribed by value of Iranian legislation (Table 2).We also found significant differences ($p<0.05$) between Physico-chemical parameters such as, pH, nitrite (NO_2^-), sodium, potassium, sulphate, ammonia, bromide, phosphate and seasons (Table 1).

These results are important, not only for the many people who drink groundwater but also for the health supervisory agencies such as Ministry of Health and Institute of Standards and Industrial of Iran (ISIRI) to have more effective control on groundwater.

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