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PIXE Elemental Analysis of Boroujerd's Tap Water

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Abstract: In this study, we carried out Particle Induced X-ray Emission (PIXE) analysis of tap water from several houses located in different parts of Borojerd city In Iran. A 2.0 MeV proton beam was employed to excite the samples. The concentration of these elements varied from one month to other depending on session but the average elemental concentrations during a complete year seams invariant. The main objective of this work was to characterize and to monitor the trace elements in drinking water, as well as to provide valuable information about the levels of heavy metallic pollutions. The experimental results of trace elements analysis of drinking water of city of Borujerd which was sampled in different months during a year, has been presented by a spectrum of X-rays (in mg/lit) and graphs of quality concentration of elements. Our results were within the permissible limits reported by International standards, and WHO guidelines for drinking water quality and could be observed that the drinking water of Borojerd lacks any toxic trace elements and heavy metals.

Keywords: Water Pollution, PIXE, Accelerator, Trace Elements

1. Introduction

Water is one of the most abundant compounds on the Earth which cannot be found in its pure form in nature; this is due to fact that being a potent solvent; it solves more or less most of the elements in its path. Human activities also lead to the pollution of water directly or indirectly. Various elements in drinking water must have concentrations below certain limits. Otherwise, they may adversely affect the health of human being by drinking. Therefore, in order to safeguard the public health and to prevent from environmental pollution it is important for us to be able to characterize the elements in drinking water, in this study, Particle Induced X-ray Emission (PIXE) analysis method has been used to identify all trace elements in Boroujerd's drinking water with $Z \geq 11$, and to determine their concentrations.

Borojerd city is locating at Lorestan province, in northeastern of Iran, with about 376000 people. The main source of drinking water of the city comes from the nearby surrounding mountains, that after collection, storage in reservoirs and purification process, it will be distributed by the city's principal system of conduction and distribution water network.

Identify the elements existing in water is of utmost importance, to have the healthy water not only for drinking but also for different use such as in agriculture, food industry, and medicine.

Generally it has been verified that a significant number of diseases are characterized by high or low value of some trace elements which are present in water, directly since about 25% of the amount of these trace elements enter in body by drinking, then a lot of attention must be paid to water pollution [1]. Biological tissues, except at low concentrations of organic compounds consisting of a series of heavier elements, which are called trace elements. By means of the usual definition, the trace elements concentration in a sample is less than 1000 ppm or 10^{-4} gr, and generally falls into two categories: essential elements and toxic elements [1], [2].

Since the estimated real contribute of heavy elements absorbed by human being, through food or water is almost identical, we can find the importance of purified and healthy water [3], [4].

For the classification of drinking water and determining the allowable amount of minerals containing there in, the international standard values, are listed in, Table 1.

Different methods for measuring trace elements in water have been suggested but the one of the most important of which is Particle Induced X-ray Emission (PIXE) [5]-[7]. The major advantages of this non-destructive method of analysis is simplicity, high performance, the ability of fast identification of elements existing in the sample (z ≥11), and high measurement accuracy of about hundredths of a milligram per liter and so forth [8], [9].

2. Methods and Materials

2.1. Elemental Analysis Using PIXE Method

Particle induced X-ray emission (PIXE), is a powerful yet non-destructive elemental analysis technique. X-rays of a characteristic energy of the element are emitted, an energy dispersive detector is used to record and measure these X-rays and then the intensities are converted to elemental concentrations. However, tests performed on Van De Graff system have produced parts per million (ppm) level measurements for certain elements, this method of analysis is one of the best techniques for elemental analysis to determine the type and amount of elements in different samples, so a small sample of the material prepared to be bombarded by the proton beam produced by a Van De Graff accelerator, with a specified energy, and then X-rays emitted from the sample will be detected with the appropriate techniques, after analysis of received dates, the elements contained therein can be determined [10], [11].

In this research, samples have been taken from drinking water of Boroujerd and in order to maintain the external parameters of the samples that are likely to enter; all water samples were collected from the same house in the town. For sampling, there has been used the water which has been flowing through the tubes a few minutes to prevent from entering deposited minerals. The sample container has been also washed several times with water sample, needed for analyzing, to reduce the undesirable entering the water. After the adding of indicator to the sample, it should be stirred until a homogeneous solution to be prepared, then a few drops of water sample put on a Kapton film and let it be dried in a clean system at a temperature of about 35°C.

To compare the drinking water used at homes with deposited water of the reservoirs, which should be distributed in the city, in order to study the possibility of some variation and any possible change in quality during the water distribution as it flows to the points of use, has been prepared a few samples of the main source of water as well as for analysis.

2.2. Experimental Set Up

The experiments were performed using the 3MeV, Van de Graff accelerator, the prepared samples put inside the target chamber then they had been bombarded by proton beam, samples were analyzed in vacuum using a beam of 2 MeV protons focused to the samples, the beam current was about 2.5 nA, characteristic X-rays, produced by bombarding the sample were detected using a Si (Li) detector positioned at an angle of 135◦ relative to the incident beam direction [12].

For improvement of measurement accuracy 25 ppm of yttrium solution has been added to samples of water (the added quantity should be as low as possible, should be considered the unavailable elements in the water as an indicator too). All the way to the target as the beam pass through the accelerator, is placed in the vacuum system to obtain, around 5^{-10} Torr. After exiting the beam from accelerator, through an appropriate transport line to deal with the target, it is placed in a magnetic field system. Two collimators are placed in the path to aligning the output beam of accelerator. Beam must be aimed during the whole process of dealing with the same intensity. Simple view of the beam path is being shown in figure 1.

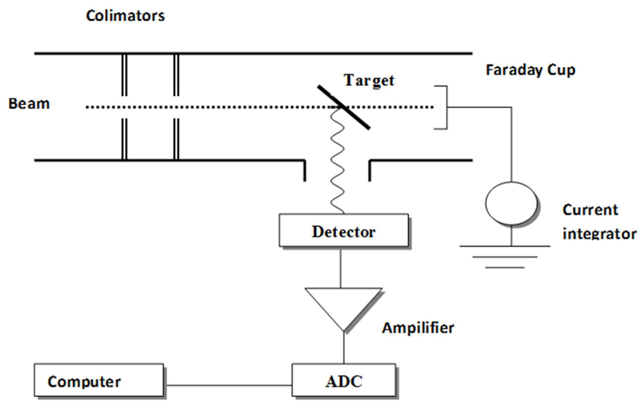

Figure 1. *A schematic overview of beam direction though the transport line.*

3. Results

This study aims to evaluate some minerals of health concern in commonly used drinking tap water in Broujerd and its comparison for different samples of household water. For PIXE analysis have been performed a series of tests according to different criteria of sampling of tap water and tap water quality was examined as a function of elemental distribution in tap water.

The mean concentrations of Mg, Al, Si, S, Cl, K, Ca, Fe, Na, Cu and Zn have been determined in tap water, using non-destructive Proton Induce X-ray Emission (PIXE) analysis. Figure 2, shows, the experimental spectrum of the X-rays obtained by analysis of trace elements containing in drinking tap water of city of Borujerd sampled in March 2012, where principal peeks of essential elements presents according to number of counts versus energy variation of characteristic X-rays. Table 1, presents maximum limits of chemical elements for drinking water as a standard reference necessary for assessment to comparison with analysis result. For the first step of sampling, table 2 represents the quantity of trace elements present in the city's drinking water (in mg/lit) in different session of year and furthermore increasing the number of samples (once per month) in order to cover all of period of sampling during a year, aimed to obtain more precision on sampling, table 3, represents the quantity of trace elements present in the city's drinking water (in mg/lit) in different months of year [13], [14].

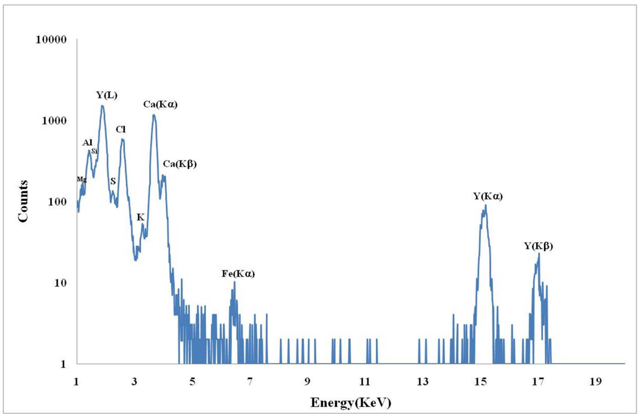

Figure 2. Experimental spectrum of X-rays of trace elements in drinking water sampled in March 2012.

Table 1. Maximum limits of chemical elements of drinking water.

element	Maximum limits (mg / lit)
Pb	0.05
Hg	0.001
Ba	1
Sb	0.005
Cd	0.005
Mo	0.07
As	0.05
Zn	3
Cu	1
Ni	0.02
Fe	0.3
Mn	0.5
Cr	0.05
V	0.1
Ca	200
Cl	400
S	130
Al	0.2
Mg	50
Na	200

Table 2. Concentration of major trace elements (in mgr/lit) in drinking water of Broujerd city sampled in different seasons.

	Zn	Cu	Na	Fe	Ca	K	Cl	S	Si	Al	Si	Mg
spring	0/01	0/02	*	0/43	11/04	4/16	7/07	6	7/26	*	7/26	4/01
summer	*	0/03	18/8	0/5	94/6	2/08	83	1/9	8/6	*	8/6	30/7
fall	0/03	0/03	8/7	0/06	52/6	2/04	41/3	0/5	4/7	*	4/7	19/5
winter	0/02	0.04	*	0/04	218	3/01	76	5/03	9/8	2/01	9/8	14/6

"*": indicates that the quantity of the element is lower than limits, in this experiment.

Table 3. The results of PIXE analysis; concentration of major trace elements (in mgr/lit) present in drinking water of Borojerd, sampled in different months.

	Zn	Cu	Na	Fe	Ca	K	Cl	S	Si	Al	Mg
Mar	0/01	*	10	0/48	146/9	4/45	69/48	7/98	13/87	8/06	10/38
Apr	0/03	0/02	*	0/29	142/56	3/7	78/99	4/55	9/9	*	8/36
May	*	0/05	*	0/25	144/28	1/32	91/93	4/23	5/4	*	2/86
Jun	0/03	*	19/5	0/06	105	3/5	91	2/5	12	*	40
Jul	0/03	0/024	17/8	0/1	54/2	2/6	55	1/6	4/6	*	27/2
Aug	0/04	0/013	17/5	0/08	104/25	1/75	47/25	3/25	6/5	2/75	31/5
Sep	0/03	0/03	10/25	0/05	59	2/5	45/75	0/5	4/25	*	24/75
Oct	0/04	0/03	10/25	0/09	50/5	1/75	34/75	4/75	5	*	22/5
Nov	0/04	0/04	7/75	0/03	49/25	1/75	38	0/5	5	*	18/75
Dec	0/01	0/05	8	0/03	83/25	3/75	92/75	6/5	10/5	*	35/25
Jan	0/02	*	*	0/65	374/19	2/5	55/69	5/46	10/11	3/68	9/48
Feb	0/03	0/04	*	0/9	193/63	*	27/26	5/46	22/8	15/47	13/14

"*": indicates that the quantity of the element is lower than limits, in this experiment.

To evaluate the quantity of elements and compare them together in a visual way have been simulated contributes of element concentration for each sampling period as show in figures 3 to 18, the first 12 figures present comparison trends of element concentrations regarding all of months of 2012, starting in March, as the first month of Iranian calendar. As can be observed for March, April, May and June, the concentration quantity for Ca and Cl, is more than 200 and 50 respectively but for Mg, Si and S, is less than 50, for other elements we have insignificant values.

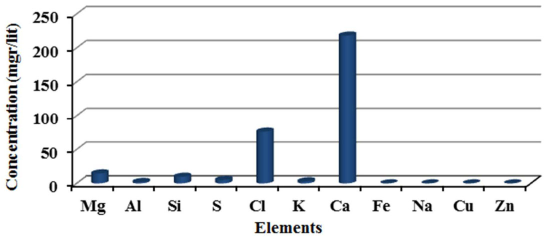

Figure 3. Medium concentration of elements in water sampled in March 2012.

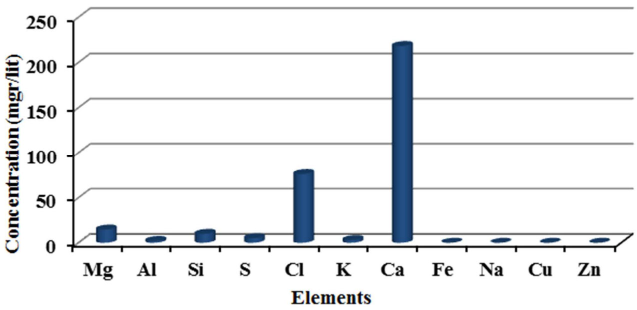

Figure 4. *Medium concentration of elements in water sampled in April.*

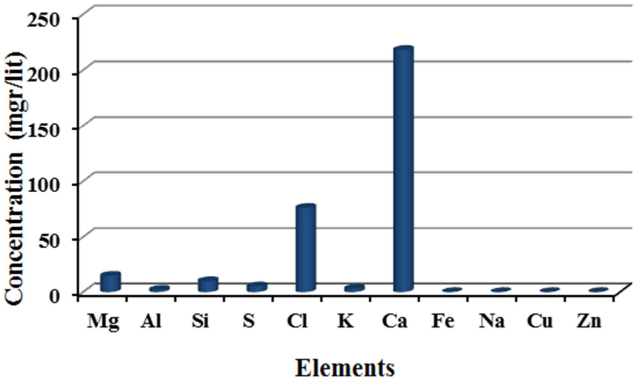

Figure 5. *Medium concentration of elements in water sampled in May.*

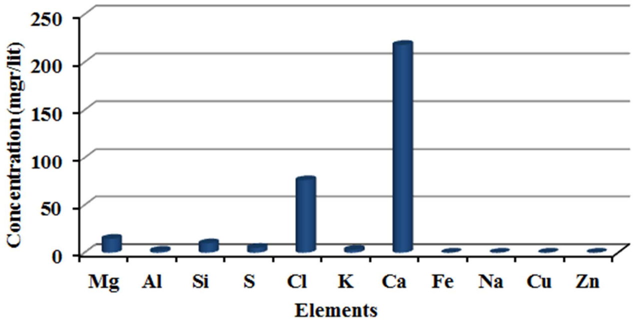

Figure 6. *Medium concentration of elements in water sampled in Jun.*

In July, August and September, concentrations values have been changed for Cl more than 80, Ca about 80, Mg about 40 and for Si, Na, S and K less than 20, figures 7- 9.

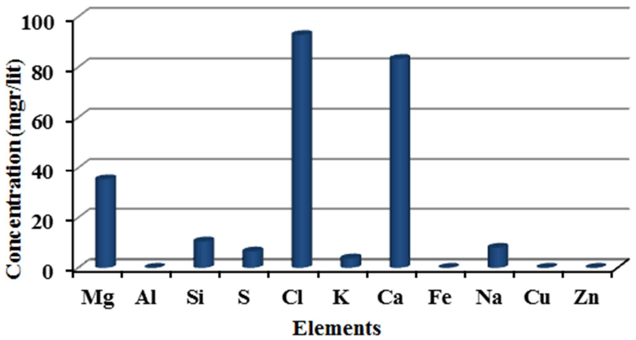

Figure 7. *Medium concentration of elements in water sampled in July.*

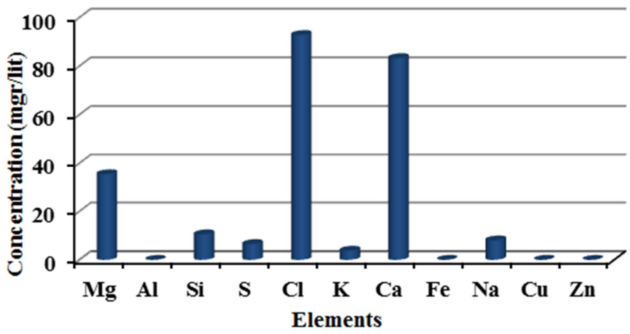

Figure 8. *Medium concentration of elements in water sampled in August.*

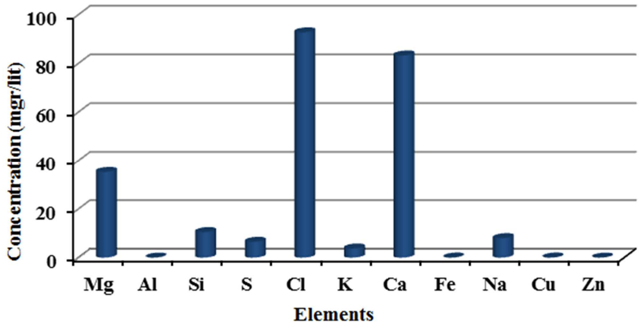

Figure 9. *Medium concentration of elements in water sampled in September.*

In October we have another period of variation value of concentration until December, for Cl and Ca less than 60, Mg more than 30 and Si, Na, S and K less than 10, figures10-12.

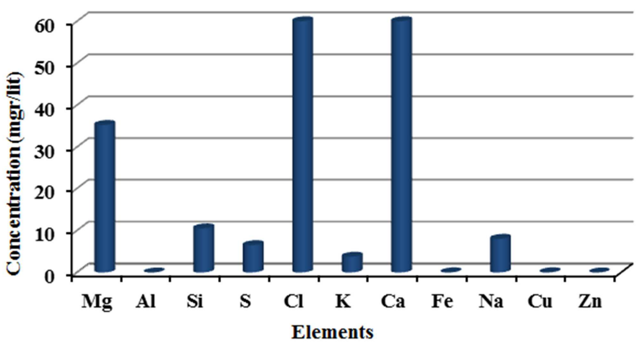

Figure 10. *Medium concentration of elements in water sampled in October.*

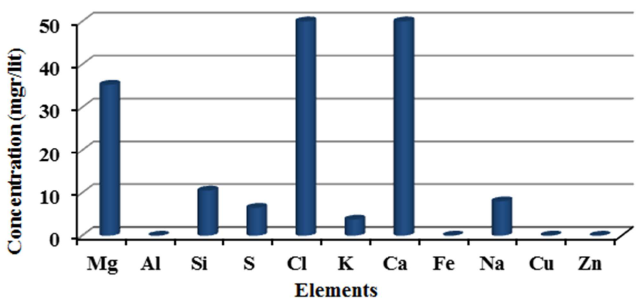

Figure 11. *Medium concentration of elements in water sampled in November.*

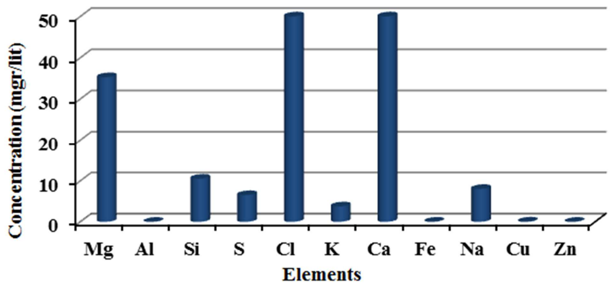

Figure 12. *Medium concentration of elements in water sampled in December.*

In January and February the situation changes as same as in March, figures 13 and 14.

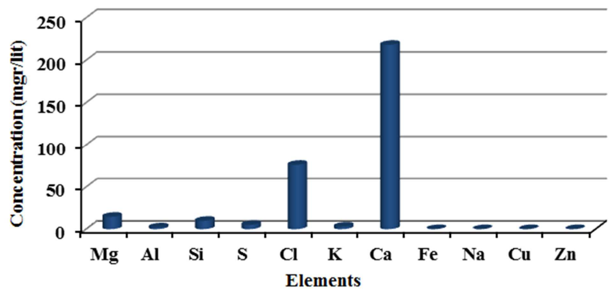

Figure 13. *Medium concentration of elements in water sampled in January.*

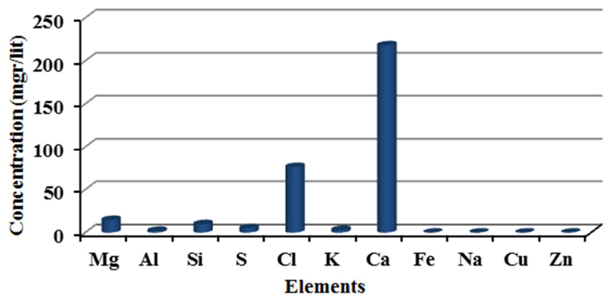

Figure 14. *Medium concentration of elements in water sampled in February.*

The second part of results regards to evaluate the quantity of elements according to every for months sampling periods and comparing the quantity of elements by a concentration trend vs. containing elements in tap water. The figures 15 to 18, present comparison trends of concentrations for each sampling season that begins in spring. Tree principal elements in spring are Ca and Cl with a concentration value more than 50 but Mg , Si, and S have values less than 50.

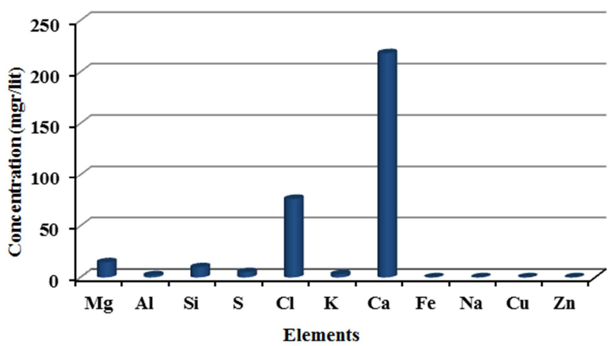

Figure 15. *Medium concentration of elements in water sampled in spring.*

During summer and fall, the results non presents any variation in concentration values as show in figures16 and 17. But in winter we can observe a significant increase of concentration for Ca, Cl, Mg, Si, S and K, due to raining water and incoming water of rivers in this season.

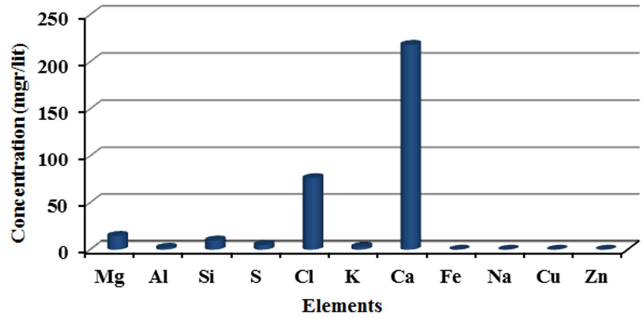

Figure 16. *Medium concentration of elements in water sampled in summer.*

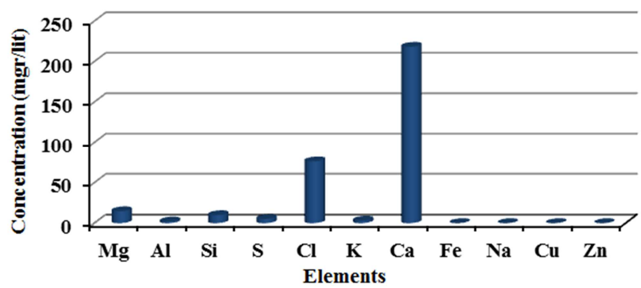

Figure 17. *Medium concentration of elements in water sampled in fall.*

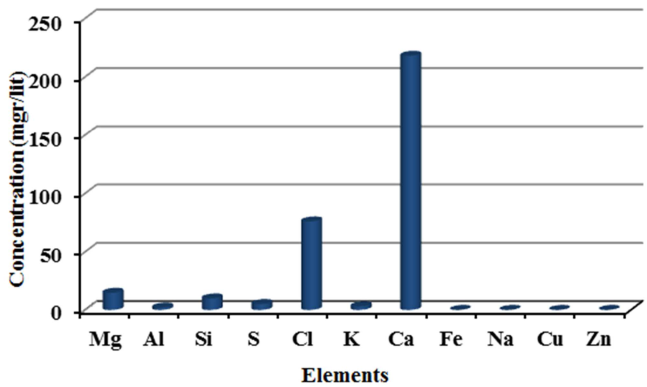

Figure 18. *Medium concentration of elements in water sampled in winter.*

4. Discussion

Regarding the subject of measurement error, in the PIXE method, as like other methods, many factors are also involved, such as: spectrum statistical error, non-uniform sampling error, the incident beam measurement error and the simulation error due to the software. In the case of trace elements measurement, statistical error value increases due to low count rate.

The relative statistical errors (due to relative characteristic of this method) except for the peaks are the same for all parameters therefore could be omitted them.

The errors which could be considered due to the amount of indicator element and the calculation of area under the peak of desired element.

In order to minimize errors in measurement methods could be extent the total area under the Peak of indicator element, has been to obtain 1,000 counts. In this case, the indicator 's error is equal to 3%, moreover considering small area which formed under the peak, the required value, will be reduced to about 20% which is mostly acceptable for such measurement.

The medium concentration of elements in water sampled in different months of a year, have been presented in figures number 3 to 14 and for the period of sampling every session of the same year(2011), the medium concentration of elements are presented in figures number 14 to 18.

As the trends show in the months of March, April, May and June quantity of concentration for major number of elements is the same but in July for Cl, S, Si, Na, and Mg increase but decrease for Ca. After July in August and September quantity of concentration stay without any significant variation. In October quantity increase for Ca, Cl, Mg, Si, S, K and Na.

In November and December the quantity of concentration for all elements remain the same as before without any significant variation. In January quantities decrease for S, Si, Mg, Cl, Ca, Na and without any significant variation remain in February.

The Results of comparison of medium concentration of elements in water which has been sampled in different sessions, spring, summer, fall, not present any significant variation as shown in figures number 15 to 17 but in winter we have increased values of element concentration due to snowing and raining climatic variation which impact water resources coming from mountains. We confirmed the increase of concentration of some elements in water taken from river due to heavy rainfall and snowfall.

5. Conclusion

By comparing tables 1 and 2, it is observed that the drinking water of Borojerd lacks any toxic trace elements such as arsenic, lead, mercury, etc. but a low average amount of some elements, such as calcium, iron and aluminum in the winter is more than limits, because it can be caused by an increase of the element during the washing of the route when it rains. In general the trace elements quantity levels in the Borujerd city water are now in good condition. This study should be established to assure that the quality of drinking water remains within acceptable national standards.

References

[1] Anan N, Action of trace element in the drinking water on the cardiovascular system, Gig. Sanit., 1987, 10, 75.

[2] Bostrom H and Waster PO., Trace elements in drinking water and death in cardiovascular disease, Acta Med. Scand., 1982, 181 (4), 465.

[3] Heck D, Ochs A, Klempnow A, Maier K and Kratt, Localized chanes of trace elements concentration within diseased human liver lobules, Nucl. Instr. And Meth. 1987, 22, 196.

[4] Doha Al Nouri, et.al., Quality Characteristics of Commonly Consumed Drinking Water in Riyadh and Effect of Domestic Treatments on Its Chemical Constituents, *Journal of Food and Nutrition Research, 2014, Vol. 2, No. 1, 25-33.*

[5] Ivankievicz Ed., Takacs S. And Kovace Z., Oral center and trace elements in drinking water, or S., 1980, 63(11), pp. 321-325.

[6] Yamazaki H. et al, PIXE Elemental Analysis of Drinking Water Supplie, *Int. J. PIXE* 12, 209 (2002).

[7] Al-Bedri M. B., Abdul Ghani J., PIXE Elemental Analysis of Mineral, Tap and Ground Water, International Journal of PIXE 20(03n04). April 2012

[8] Mourkides, G. A. et al. Remove from marked Records Elemental analysis of water and sediments by external beam PIXE. Chemistry and Ecology 1990, Vol. 4 No. 2 pp. 65-83.

[9] Prasad A. Essential trace elements in human health and disease, J. Am. Coll. Nutr., 4(1), 1985, pp.1-2.

[10] Takacs S. Dental caries and trace elements in drinking water, Drv. Hetil., 1982, 113(20), pp.1062-1064.

[11] Johansson, S. A. E, Campbell J. L, Malmqvist K. G, "Particle Induced X-Ray Emission Spectrometry", John Wiley & sons, October 1995.

[12] Van Grieken R. Operational guide on Sampling Storage and Sample preparation procedures for XRF Analysis of Environmental Materials, IAEA, 1996.

[13] Farshid E., Rezaei D., Ansarinejad A., Proton interaction with material in low energy and application's in analysis materials, 4^{th} National Conference of Physics of Particles and Fields, 22-23 January 2013, Azad University of Tehran. Proceeding, pp. 192-195

[14] W.H.O., Guideline for Drinking Water Quality, Geneva, 1993.

[15] Zuane J. Handbook of Drinking Water Quality Standards and controls, Van Nostrand Reinhold, 1990, 17.