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Evaluation of Physicochemical Parameters of Drinking Water and Investigating the Performance of Several Purification Methods on Water Quality of Some Universities in Iran, 2022

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ABSTRACT

Background: Water quality is the most important factor for consumers. Therefore, monitoring and controlling water quality is of particular significance in different human communities such as universities. The aim of this study was to investigate the quality of drinking water in some universities in Iran. **Methods:** In this study, the physicochemical parameters and heavy metals including lead, cadmium, nickel, arsenic, and chromium in drinking water were determined in nine Iranian universities. Then, the efficacy of several treatment methods was evaluated in the removal of heavy metals, including boiling process in two stages, 5 min boiling, 5 h boiling, and filtration process. **Results:** Physicochemical properties of drinking water in all samples were appropriate. Hardness levels were higher than the World Health Organization standards. However, this parameter was lower than the national standard of Iran (500 mg/l $caco_3$). Nevertheless, cadmium content was not detected in any samples, and nickel and chromium content was below the permissible limit. Lead content was equal to the limit in three samples, and arsenic content was equal to the limit in four samples. Water purification methods including boiling and water purifier were satisfactory and significantly reduced pollutants. **Conclusion:** It is suggested to check drinking water quality in universities randomly.

Keywords: *Physicochemical; Heavy metals; Water pollution; Water purification*

Introduction

Water plays a vital role in human life, and water quality is one of the significant health issues affecting the health of individuals and society (Salari *et al.*, 2020). Therefore, the World Health Organization (WHO) has identified healthy water resources as one of the most important health indicators in developing countries. Expansion of agricultural, industrial, and social developments has led to water pollution and degradation of quality, and on the other hand, population growth has increased water consumption. Therefore, periodic monitoring and quality control of water resources are inevitable (Behboudi *et al.*, 2017, Salari *et al.*, 2018, World Health Organization, 2008). Heavy metals are serious challenges in drinking water resources and are a global concern due to their toxicity to human health and the environment. Accordingly, it is necessary to monitor these

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elements in drinking water, constantly (Özkara and Akyıl, 2018, Tchounwou *et al.*, 2012). Exposure to heavy metals can cause skin disorders, respiratory cancer, depression, anemia, heart failure, reproductive disorders, decreased immunity, gastrointestinal disorders, and death (Mohod and Dhote, 2013, Salmani *et al.*, 2016). Nickel is a heavy metal that is abundantly found in the earth's crust and is widely used in industry due to its physical and chemical properties (Salmani *et al.*, 2016). Numerous studies have suggested that producing reactive oxygen and oxidative stress are action mechanisms of heavy metals such as arsenic, cadmium, lead, and chromium (Pirsaheb *et al.*, 2015, Tchounwou *et al.*, 2012). Arsenic has been reported to be a concern for environmental and biological health and identified as a toxic element due to its influence on the sulfhydryl group (Salmani *et al.*, 2018, World Health Organization, 2003). The Physicochemical properties of water can affect the public acceptance of water (Farhadkhani *et al.*, 2014, Sorlini *et al.*, 2013). Hardness above 200 mg/l causes deposits in pipes and distribution systems as well as reducing water purification power. Furthermore, a hardness of less than 100 mg/liter can cause corrosion (Davoudi *et al.*, 2016). The presence of minerals causes turbidity and suspension of organic matter in water, and in most cases, microorganisms also attach to these compounds. High turbidity destroys the clarity of the water, leading to consumers' dissatisfaction and gastrointestinal diseases (Muthuraman and Sasikala, 2014, Schwartz *et al.*, 2000). Considering the importance of water health and hygiene, in recent years, water purifiers have become very common in various parts of the world, including the Middle East. Water purifiers include reverse osmosis devices and semi-industrial pre-treatment devices (Owa, 2013, Wimalawansa, 2013). Boiled water is recommended in most communities when poisoning epidemics occur (Brown and Sobsey, 2012). On the other hand, the process of boiling water can affect its quality (Kayaga and Reed, 2011). Given the pivotal role of water in human life and since water hygiene can affect the health of the university community as a centralized place, the present study monitored the physicochemical quality of drinking water in major universities of Iran. Continuation of the efficiency of two water treatment techniques, including boiling water in two stages of 5 min and 5 h, and filtration of water was evaluated in this study.

Materials and Methods

Sample collection and preparation: The present cross-sectional study investigated physicochemical properties and heavy metals contents in the urban water distribution network of nine major universities in Iran. Forty samples of drinking water were analyzed, and 1-liter plastic containers were used to collect samples. These containers were thoroughly washed and dried with distilled water before filling them with water samples. The physicochemical parameters such as turbidity, electrical conductivity, hardness, alkalinity, calcium, and magnesium ions were analyzed according to the standard method.

Measurement of heavy metals: Ten milliliter of standard solutions (1000 mg/l) of each element was transferred to a 100 ml volumetric flask. Then, it was diluted with 100% nitric acid to a volume of 100 ml and mixed well. The resulting solution had a concentration of 100 mg/l or 100 ppm of the desired element. The optimal wavelength was selected according to **Table 1**. Blank samples and standards were injected, and the standard curve was drawn. Drinking water samples were analyzed by the ICP (Inductively Coupled Plasma, model: SpectroAcrose-76004555, Made in Germany).

Water boiling: Samples were prepared in three replicates from the desired drinking water. The boiling operation was performed in two stages of boiling for 5 minutes and 5 hours in electric kettles separately, and then the heavy metals of the samples were analyzed.

Pre-filtration of water: A semi-industrial household water treatment device (HWTD) was installed on the inlet of consumer water (**Figure 1**), and the sample of purified water was taken from the outlet and examined for heavy metal concentration. This device was made in Thailand by a Soft Water Company and includes three stages of pre-treatment, two treatment pumps, two transformers, and four membranes of 100 gallons (each membrane has 13 layers), and activated carbon.

Data analysis: One-way analysis of variance (ANOVA) was performed, and the significant differences between the films properties were determined with Duncan's multiple range tests using the SPSS software (SPSS 21, SPSS Inc., Chicago, IL, USA).

Results

Table 1 summarizes results of the level of heavy metals levels in the samples taken from different places. Results of physicochemical analysis are presented in **Table 2**.

According to **Table 2**, cadmium was not found in any of the samples. The highest amount of arsenic with mean value of 10.72±0.07 µg/l was in the university drinking water sample with code 6 and the lowest amount of this toxic metal was in the university drinking water sample with code 4 with mean value of 6.50±0.14 µg/l. Chromium was not found in 5 samples of university water and in other samples its concentration was below the standard. Lead was found in the drinking water of all universities. Nickel was not found in eight samples of drinking water from the universities and its value in other samples was below the allowable limit.

The efficiency of water treatment methods is shown in **Figures 2.**

The removal efficiency of treatment methods showed that the process of boiling water for 5 minutes can reduce arsenic in water by about 45.27% and boiling for 5 hours showed a decrease of about 51.5%. The results of reducing nickel concentration under different processes showed that boiling water for 5 hours could have a greater reduction in the content of nickel. The results showed that after boiling water in both different times, the amount of lead was undetectable. The results of the study of chromium concentration in water after treatment processes showed that due to the fact that the initial amount of metal in the control sample was less than the standard and insignificant, it was undetectable in all three treatment processes. The results showed that cadmium concentration reached an undetectable range after the impact of three treatment processes.

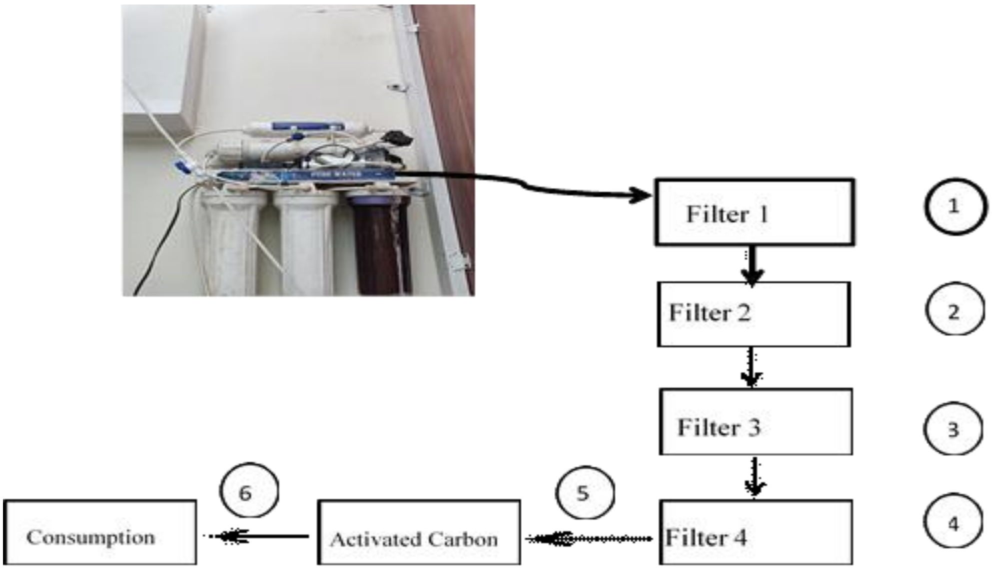

Figure 1. Schematic of the HWTD process.

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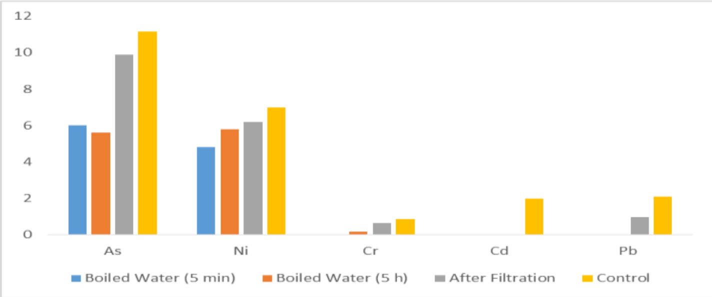

Figure 2. Effect of refine processes on heavy metals content level.

Table 1. Heavy metals (μg/l) in drinking water (N=40).

Sampling location number	Arsenic	Nickel	Chromium	Cadmium	Lead
Mashhad. Point 1	10.17 ± 0.03	BDL	BDL	BDL	BDL
Mashhad. Point 2	10.18 ± 0.06	BDL	BDL	BDL	BDL
Gilan	8.64 ± 0.06	3.54 ± 0.40	BDL	BDL	8.45 ± 0.70
Kerman	8.50 ± 0.05	1.87 ± 0.09	5.31 ± 0.07	BDL	10.7 ± 0.16
Hamedan	6.50 ±0.14	BDL	1.81 ± 0.04	BDL	3.10 ± 0.16
Tehran- place-1	BDL	BDL	0.06 ± 0.00	BDL	10.6 ± 0.13
Sabzevar	10.72 ± 0.07	4.62 ± 0.10	4.68 ± 0.25	BDL	3.87 ± 0.04
Shiraz	BDL	1.82 ± 0.00	1.42 ± 0.04	BDL	4.70 ± 0.03
Qom	BDL	BDL	BDL	BDL	9.04 ± 0.15
Esfahan	7.50 ± 0.08	2.93 ± 0.10	8.60 ± 0.21	BDL	4.48 ± 0.06
Tehran- place-2	BDL	BDL	BDL	BDL	1.88 ± 0.06
Tehran- place-3	BDL	BDL	0.05 ± 0.01	BDL	1.97 ± 0.02
Tehran- place-4	BDL	BDL	BDL	BDL	10.6 ± 0.12

BDL: Below Detection Limit.

Table 2. Physicochemical parameters.

Sample location	Mg++ (mg/l)	Ca++ (mg/l)	Alkality (mg/l)	Hardness ($CaCO_3$(mg/l))	Turbidity (NTU)	Conductivity (µs/cm)
Mashhad. Point 1	23.9 ± 0.2	72.8 ± 0.7	167 ± 0.8	280.0 ± 0.1	0.3 ± 0.4	720.0 ± 0.5
Mashhad. Point 2	34.6 ± 0.1	79.2 ± 0.3	141.0 ± 0.1	340.0 ± 0.1	0.2 ± 0.0	1083.0 ± 0.2
Gilan	69.3 ± 0.1	83.4 ± 0.2	192.0 ± 0.7	48.0 ± 0.6	0.3 ± 0.3	666.0 ± 0.2
Kerman	30.2 ± 0.1	52.8 ± 0.5	208.0 ± 0.2	256.0 ± 0.3	0.2 ± 0.0	1021.0 ± 0.8
Hamedan	13.6 ± 0.9	62.4 ± 0.2	170.0 ± 0.3	212.0 ± 0.3	0.7 ± 0.2	664.0 ± 0.8
Tehran- place-1	9.0 ± 0.1	56.0 ± 0.1	80.0 ± 0.4	180.0 ± 0.5	0.4 ± 0.0	431.0 ± 0.2
Tehran- place-2	7.3 ± 0.1	60.0 ± 0.5	73.0 ± 0.2	181.0 ± 0.2	0.3 ± 0.0	372.0 ± 0.3
Tehran- place-3	8.2 ± 0.1	58.4 ± 0.1	82.0 ± 0.8	178.0 ± 0.6	0.3 ± 0.0	413.0 ± 0.9
Tehran- place-4	11.2 ± 0.6	53.6 ± 0.1	75.0 ± 0.2	183.0 ± 0.1	0.2 ± 0.0	402.0 ± 0.9
Shiraz	39.5 ± 0.5	87.2 ± 0.7	226.0 ± 0.8	380.0 ± 0.9	0.2 ± 0.0	917.0 ± 0.9
Qom	10.7 ± 0.1	45.6 ± 0.7	208.0 ± 0.9	158.0 ± 0.7	0.05 ± 0.02	326.0 ± 0.8
Esfahan	12.1 ± 0.1	56.0 ± 0.2	164.0 ± 0.3	190.0 ± 0.3	0.61 ± 0.02	433.0 ± 0.9
Sabzevar	28.5 ± 0.2	43.2 ± 0.1	207.0 ± 0.5	108.0 ± 0.1	0.62 ± 0.02	1365.0 ± 0.9
WHO	150	200	500	100	5	-

The physicochemical properties of drinking water of the studied universities are presented in Table 2. Comparing the obtained results with the standard of the WHO shows that most of the studied parameters were within the standard and there was only discrepancy in the case of hardness. The results showed that the hardness in all samples was higher than the desired level of the WHO but the amount of hardness was less than the recommended amount of the Iranian national standard (500(mg/l)).

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Discussion

Water is a vital element without which life cannot exist. Water contains important minerals and salts that are essential for the body (Sadeghi *et al.*, 2007). However, the decrease or increase of some of these minerals lead to various problems and diseases (Marzban *et al.*, 2017). In the present study, the results of monitoring the physicochemical properties of water showed that most of the studied parameters are below the limit reported by the WHO. The only parameter which was higher than the desired limit recommended by the WHO in all the samples was water hardness. According the national standard of Iran, the permissible limit is 500 mg/l, showing that there is no problem. The turbidity of the examined samples was acceptable. This issue is very important regarding the public acceptance of water (Ngari *et al.*, 2013). Examination of heavy metals in drinking water samples of different universities showed that some metals in some samples were equal to the recommended standard value (10 mg/l) in some samples (Inui *et al.*, 2012). The amount of arsenic in the university with codes 1-1, 1-2, and 6 was equal the allowable level, and it is necessary to take the necessary measures to follow up the pollution and remove it. Previous studies have indicated that due to the abundance and presence of more arsenic in the Earth's crust, the possibility of this metal in groundwater and surface water sources is high. Therefore, reconsidering the source of drinking water should be a necessary measure to take (Gul *et al.*, 2015). Cadmium was not found in any of the samples. Not detecting cadmium in water can also be related to the safety of water distribution pipes. On the other hand, sediments deposited on the inner body of the distribution pipes themselves are a barrier to releasing this metal into the water of the municipal network (Ma *et al.*, 2021). Numerous studies have been conducted on the quality of drinking water in Iran in different cities, revealing that other sources of drinking water supply are desirable in terms of safety and health except for a few cases (Bairagh and Nasehi, 2016). Alidadi *et al.* investigated the concentration of heavy metals and fluoride in the drinking water network of Mashhad city (Ghaderpoori *et al.*, 2019, Peiravi *et al.*, 2013). The results were similar in some of heavy metal measurements. The concentration of lead in drinking water samples of universities with codes Kerman, Tehran place-1, Tehran place-2 was equal the allowable limit (10 mg/l). The presence of lead in drinking water can have several reasons. The drinking water samples studied were collected from different parts of the country with different climatic conditions, which can justify the dispersion of the studied parameters. The present study results showed that the amount of chromium in all samples was below the standard limit (50 µg/l). The amount of nickel in all samples was reported below the standard limit, except in the samples with Qom, where the reported amount was declared higher than the allowable limit. Evaluating the effect of boiling processes on the content of heavy metals in water revealed that in boiling for 5 minutes technique, compared to boiling for 5 hours, almost the same amount of heavy metals were removed. Hence, it can be considered that boiling water for fewer amounts of time and with less energy consumption can be a cost-effective and fast strategy for water treatment. Also, comparing the efficiency of boiling methods with filtration showed that the reduction rate of toxic metals in the filtration method was less, providing the basis for further research.

Velayatzadeh *et al.* investigated the effect of household water purifiers on the concentration of metals in drinking water in Ahvaz city (Velayatzadeh and Payandeh, 2020). The results showed that household water purifiers reduced heavy metals, which is similar to the results of the present study. A review of previous studies on heavy metals concentration in drinking water of different cities in Iran showed that no comprehensive study has been conducted on the quality of drinking water in universities as a centralized place (Ghaderpoori, 2018, Pirsaheb *et al.*, 2015). Brief studies have also been conducted in the cities under study. Consequently, studying

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the quality of drinking water and its continuous monitoring is of utmost significance and can be an essential issue for research.

The present study has some limitations including: 1) it was not possible to conduct sampling and survey the quality of drinking water in universities across the country, 2) examining other treatment methods on the quality of drinking water was not possible due to the high cost, and 3) it was not possible to analyze the amount of other important pollutants.

Conclusion

The present study results showed that continuous monitoring of drinking water resources in centralized places such as universities is one of the necessities for maintaining consumers' health. If possible, with further studies, water purifiers can be used to make drinking water taste better. It is also possible to improve the hygienic quality of water and prevent secondary contamination by boiling for a short time (5 minutes).

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Conflicts of interest

None declared.

Authors' contributions

Rezaei Z, Khanzadi S, Shamloo E and Salari A designed the study; Salari A and Rezaei Z conducted the study, analyzed the data, and drafted the manuscript. All the authors read, revised, and approved the final manuscript.

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References

Bairagh LR & Nasehi F 2016. Zoning release of heavy metals in the ground water of Karaj plains, Tehran. *Bioscience biotechnology research communications.* **9 (2)**: 253-261.

Behboudi A, Jafarzadeh Y & Yegani R 2017. Polyvinyl chloride/polycarbonate blend ultrafiltration membranes for water treatment. *Journal of membrane science.* **534**: 18-24.

Brown J & Sobsey MD 2012. Boiling as household water treatment in Cambodia: a longitudinal study of boiling practice and microbiological effectiveness. *American journal of tropical medicine and hygiene.* **87 (3)**: 394-398.

Davoudi M, et al. 2016. The investigation of chemical quality and stability indices of drinking water in rural areas of Taybad City in 2015-16. *Journal of Torbat Heydariyeh University of medical sciences.* **4 (2)**: 4-13.

Farhadkhani M, et al. 2014. Assessment of drinking water quality from bottled water coolers. *Iranian journal of public health.* **43 (5)**: 674.

Ghaderpoori M 2018. Heavy metals analysis and quality assessment in drinking water–Khorramabad city, Iran. *Data in brief.* **16**: 685.

Ghaderpoori M, et al. 2019. Health risk assessment of fluoride in water distribution network of Mashhad, Iran. *Human and ecological risk assessment: An international journal.* **25 (4)**: 851-862.

Gul N, Shah MT, Khan S, Khattak NU & Muhammad S 2015. Arsenic and heavy metals contamination, risk assessment and their source in drinking water of the Mardan District, Khyber Pakhtunkhwa, Pakistan. *Journal of water and health.* **13 (4)**: 1073-1084.

Inui T, et al. 2012. Determination of heavy metals at sub-ppb levels in water by graphite furnace atomic absorption spectrometry using a direct introduction technique after preconcentration with an iminodiacetate extraction disk. *American journal of analytical chemistry.* **3 (10)**: 683-692.

[DOR: 20.1001.1.24767417.2023.8.3.3.3]

[DOI: 10.18502/jnfs.v8i3.13282]

Kayaga S & Reed B 2011. Emergency treatment of drinking water at the point of use. World Health Organization.

Ma K, et al. 2021. Role of typical pipes in disinfection chemistry within drinking water distribution system. *Water supply.* **21 (3)**: 1263-1276.

Marzban A, Rezaei Z, Karkhane M, Marzban H & Eslami H 2017. Surveying the knowledge, attitude and performance of lactating women of Yazd city about heavy metals transmitted from breast milk. HOZAN. *A scientific journal of environmental sciences.* **2 (2)**: 1-10.

Mohod CV & Dhote J 2013. Review of heavy metals in drinking water and their effect on human health. *International journal of innovative research in science, engineering and technology.* **2 (7)**: 2992-2996.

Muthuraman G & Sasikala S 2014. Removal of turbidity from drinking water using natural coagulants. *Journal of industrial and engineering chemistry.* **20 (4)**: 1727-1731.

Ngari MS, Wangui WT, Ngoci NS & Wa BMJ 2013. Physico-chemical properties of spring water in kabare and baragwi locations, Gichugu Division Kirinyaga County of Kenya. *IJSR.* **2**: 280-282.

Owa F 2013. Water pollution: sources, effects, control and management. *Mediterranean journal of social sciences.* **4 (8)**: 65-65.

Özkara A & Akyıl D 2018. Environmental Pollution and Pollutants on the Ecosystem: A Review. *Türk bilimsel derlemeler dergisi.* **11 (2)**: 11-17.

Peiravi R, Alidadi H, Dehghan AA & Vahedian M 2013. Heavy metals concentrations in Mashhad drinking water network. *Zahedan journal of research in medical sciences.* **15 (9)**: 74-76.

Pirsaheb M, Khamutian R & Pourhaghighat S 2015. Review of heavy metal concentrations in Iranian water resources. *International journal of health and life sciences.* **1 (1)**: 35-45.

Sadeghi G, Mohammadian M, Nourani M, Peyda M & Eslami A 2007. Microbiological quality assessment of rural drinking water supplies in Iran. *Journal of agriculture & social sciences.* **3 (1)**: 31-33.

Salari A, Khanzadi S & Rezaei Z 2018. Survey of Fluoride, Chlorine, Potassium, Sodium, and Trihalomethane contents in the drinking water of five major universities in Iran. *Journal of advances in environmental health research.* **6 (4)**: 202-209.

Salari A, Khanzadi S & Rezaei Z 2020. Nitrate and Nitrite Concentration in the Drinking Water of Some Universities in Iran. *Journal of nutrition, fasting and health.* **8 (3)**: 141-144.

Salmani MH, Mozaffari-Khosravi H & Rezaei Z 2016. The nickel concentration in breast milk during the first month of lactation in Yazd, Center of Iran. *Biological trace element research.* **174 (1)**: 65-70.

Salmani MH, Rezaie Z, Mozaffari-Khosravi H & Ehrampoush MH 2018. Arsenic exposure to breast-fed infants: contaminated breastfeeding in the first month of birth. *Environmental science and pollution research.* **25 (7)**: 6680-6684.

Schwartz J, Levin R & Goldstein R 2000. Drinking water turbidity and gastrointestinal illness in the elderly of Philadelphia. *Journal of epidemiology & community health.* **54 (1)**: 45-51.

Sorlini S, Palazzini D, Sieliechi JM & Ngassoum MB 2013. Assessment of physical-chemical drinking water quality in the Logone Valley (Chad-Cameroon). *Sustainability.* **5 (7)**: 3060-3076.

Tchounwou PB, Yedjou CG, Patlolla AK & Sutton DJ 2012. Heavy metal toxicity and the environment. *Molecular, clinical and environmental toxicology.* **3**: 133-164.

Velayatzadeh M & Payandeh K 2020. Effect of household water treatment on the concentration of heavy metals of drinking water in Ahvaz city. *Iranian south medical journal (ISMJ).* **22 (6)**: 402-414.

Wimalawansa SJ 2013. Purification of contaminated water with reverse osmosis: effective solution of providing clean water for human needs in developing countries.

International journal of emerging technology and advanced engineering. **3 (12)**: 75-89.

World Health Organization 2003. Arsenic in drinking-water: Background document for development of WHO guidelines for drinking-water quality. World Health Organization.

World Health Organization 2008. Guidelines for drinking-water quality: second addendum. Vol. 1, Recommendations. World Health Organization.