Qualitative and health-related evaluation of point-of-use water treatment equipment performance in three cities of Iran

Salimeh Rezaeinia¹ · Simin Nasser^{2,3} · Masoud Binesh³ · Farid Ghalambor Dezfuli⁴ · Safieh Abdolkhani⁵ · Mitra Gholami¹ · Neamat Jaafarzadeh⁶

Received: 18 July 2018 / Accepted: 5 September 2018 / Published online: 19 September 2018
© Springer Nature Switzerland AG 2018

Abstract

Background Application of the point-of-use water treatment (POU-WT) systems has consistently increased during the last decade in Iran. In this study, the qualitative performances of reverse osmosis-based POU devices in selected cities of Iran were investigated.

Methods This applied- descriptive study was conducted in three cities of Tehran, Rasht, and Ahvaz in 2016 (selected based on the level of POU devices sale index in three phases). After choosing the most popular five brands of six stages POU devices, 360 water sampling zones and POU consumer households of the selected cities were measured. Also, the awareness of the consumers about POU-WT systems selection and performance was investigated through a designed questionnaire.

Results The qualitative parameters in the three cities were acceptable ($p < 0.05$) for tap water (except for EC in Ahvaz), the output water were as follows: pH = 6.05–7.5, EC = 49.8–58.2 $\mu\text{S}/\text{cm}$, TOC = 0.01–0.23 mg/L and Nitrate = 0.52–4.5 mg/LNO₃ (lower or within the range of regulatory limits), Total Hardness = 33–41.5 mg/L and Fluoride = 0.01–0.23 mg/L (which were lower than the admissible limit, with $p < 0.05$), HPC values were in the range of 543–676 CFU/mL, which exceeded the regulatory level. Results of ANOVA analysis showed significant differences between the selected cities. The results of the questionnaire survey showed that the dissatisfaction of tap water quality and health-related concerns were the two main reasons for household POU-WT systems; awareness levels of 64% of these households about the performances of their POU systems were weak. Also, social media were mostly used by POU-WT users for brand selected.

Conclusion Based on the results of the tap-water quality application of POU-WT systems are not recommended in Tehran and Rasht, and regarding the outputs of these systems, side effects of softened water, lack of Fluoride and a remarkable increase of the number of bacteria should be considered. In Ahvaz, application of POU-WT systems can decrease the

health-related problems and it is necessary to increase the access to read POU-WT efficiency information for the consumers.

- ✉ Simin Nasser
naserise@tums.ac.ir
- ✉ Mitra Gholami
gholamimitra32@gmail.com
- ✉ Neamat Jaafarzadeh
jaafarzadeh-n@ajums.ac.ir

Keywords Point- of -use water treatment system · Drinking water quality · Microbial contamination · Tap water

- ¹ Department of Environmental Health Engineering, Iran University of Medical Sciences, Tehran, Iran
- ² Center for Water Quality Research, Institute for Environmental Research, Tehran University of Medical Sciences, Tehran, Iran
- ³ Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
- ⁴ Department of Environmental Engineering, Faculty of Water Science Engineering, Shahid Chamran University of Ahvaz, Ahvaz, Iran
- ⁵ Ahvaz Health Care Office, Ahvaz Jundishapour University of Medical Sciences, Ahvaz, Iran
- ⁶ Environmental Technologies Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

Introduction

Safe drinking water and convenient sanitation are crucial for poverty reduction, sustainable development and for attaining any and every one of the Millennium Development Goals [1].

Besides, it is a principal to establish an effective policy on health and well-being protection [2]. According to the World Health Organization (WHO), between 50 and 100 l of water per person per day is needed to ensure that most basic needs

are met and few health concerns arise [3]. Hence, the quality of drinking water has progressively been questioned from a health viewpoint in recent decades [4]. The contamination of urban water supply can be caused by various sources, such as water distribution system's pollution [5]. Extensive data principally received at a governmental level from most area announced that the tap water characteristic in Iran meets drinking water standards [2]. However, some people are more inclined to use many Point-Of-Use (POU) Water Treatment (POU-WT) systems especially Reverse Osmosis (RO)-based POU systems. It is made an increasingly common due to extensive advertising by sellers and the public worries about drinking water supplies quality such as aesthetic characteristics (taste and odor), Hardness, fluoride, nitrate, and etc. [6]. The POU-WT systems are marketed as being effective to remove undesirable odors and tastes and to eliminate any unpleasant pollution in the tap water. Based on USA Water Quality Association (WQA) report, there are at least 325 POU-WT producers which means that 41% of all American houses consumed such systems in 2000 [7].

Generally, RO-based POU-WT systems are a multi-stage system that has pretreatment, post-treatment stages, and an RO membrane unit. Pretreatment contains sediment filters or microfilters and activated carbon. Post-treatment also contains activated carbon filters [8]. Such systems are usually situated at purifying tap water from a public water supply and can be located under the kitchen sink. The monitoring and maintenance are one of the important issues to use the POU-WT systems. The maintenance of these systems includes the displacement of pre, post- filters every 6 to 18 months, exhausted membrane 2 to 3 years, and cleaning of storage. The price of the system charges, according to the different brands and the flow rate is within the range of US\$ 200 to 700. Their annual operation charges are about US\$ 85–135 [9]. In general, the most usual drawback of RO-based POU-WT systems includes complex and relatively expensive installation process, service and replacement requirement, a distinctive source water quality, and the probability of bacterial growth [6, 9–11].

Fahiminia et al. [12]. Analyzed the data from 240 water samples in the input and output of different POU-WT systems in Iran and concluded that these systems were able to decrease the dissolved solids more than 90% and produce soft water. A number of heavy metals removed by POU-WT systems varied from 5% for Al to 86% for Cd and their removal average were 43%. Adel et al. [13] investigated the efficiency of domestic water filters in Kuwait and showed that the RO filter was exposed to severe damage by the residual chlorine in the water. The impaired membrane unable to decrease water salinity effectively and causing high total bacteria counts in the filtered water. Tarun et al. [14] studied Attenuation of Trace Organic Compounds (TOC_s) in Water by POU-WT systems demonstrated that these devices have the high capacity to remove

significant amounts of organic contaminants in water. However, removal of a specific compound depends on its molecular properties, treatment technology, water quality and the lifetime of the cartridge.

In view of the above, this work focuses on evaluation of the tap water, and RO-based POU-WT systems quality in a residential areas of Tehran, Rasht, and Ahvaz, compare analysis of the selected water types with the regulatory guidance (Institute of Standards and Industrial Research of Iran (ISIRI)), (World Health Organization (WHO)), (US Environmental Protection Agency (US-EPA)), with emphasis on the health impact, and an assessment of the necessity to utilize the POU-WT instead of the tap water and users awareness.

Materials and methods

This applied-descriptive study was carried out in order to investigate the chemical and microbiological quality of POU-WT systems which was installed in the residential houses of Tehran, Rasht, and Ahvaz cities of Iran, in 2016.

Description of study area

Tehran, the capital of Iran, is situated at an altitude of 1100–1800 m above sea level and within the residents of 11.7 million, with 730 km² area. The drinking water in Tehran was supplied by treated five water treatment plants (70%) and 480 wells 30%. Rasht, the center of Gilan province, is located in the north of Iran and southwest of the Caspian Sea, with a total population of 748,711. The source of drinking water in Rasht is the Bijar Reservoir Dam, which is located in Bijar, 35 km from Rasht, on the Zilaki River. Ahvaz, the center of Khuzestan province, with a total population of 1,302,000, is located in the south of Iran as one of the major metropolises in Iran. Karoon River is the source of drinking water for the city of Ahvaz (Fig. 1).

RO-based POU water treatment

The POU-WT systems studied in this survey was designed to generate between 10 to 12 l of drinking water per day. Each six stages POU-WT systems includes 5- μ m sediment filter, a carbon pre-filter, a cellulose-acetate RO membrane, 1- μ m sediment filter, a carbon post-filter, mineral filter and a small storage tank. The POU-WT systems were the NSF-certified protocol for aesthesis effects and reverse osmosis (NSF / ANSI 42, NSF / ANSI 58). The age of facility of POU-WT systems studied such as used filters in three cities was between two to six months.

Fig. 1 Location of study cities on Iran map

Sample collection

A total of 360 water samples from the input (tap water) and output of three most common POU-WT brands were collected according to Cochran's sample size and randomly from private homes. The selected brands cover almost 68% of the Iran market. The collection, conservation, and analysis of samples were performed according to standard methods for water quality examination [15]. The analyzed parameters were pH, Electrical Conductivity (EC), Hardness, Nitrate, Fluoride, Total Organic Carbon (TOC) and microbial tests (Heterotrophic Plate Count (HPC), Total Coliform Count (TCC) and Fecal Coliform Count (FCC) at the standard conditions.

Consumer awareness of POU systems

In order to investigate the knowledge and training of people who consume the POU-WT systems were considered questionnaire-based surveys. In the preliminary investigation, the numbers of residential areas which use these kinds of systems were identified. From this preselected set of residents, 100 home were randomly chosen in each studied city. Then questionnaires and face-to-face interviews were carried out with these 100 participants. The questionnaires completed during the study consisted of two parts. The first determined the general information and personal background of the participants, such as their family name, age, gender, education level and occupation. The second one focused on the condition of operation and maintenance, user's knowledge, information and satisfaction, conducting quality tests, and guidance by device providers. The information about POU-WT systems was gathered from manufacturers and sellers.

The validity of the questionnaire was evaluated using content validity. To do so, the intended questionnaire was given to 20 faculty members of the Faculty of Health of Tehran and Iran University of Medical Sciences to be examined based on the objectives of the study and the questions relating to attitude and awareness. Furthermore, the reliability of the questionnaire was evaluated using Cronbach's alpha ($\alpha = 0.86$) [16].

Analytical procedure

Physicochemical analyses

The pH and EC were analyzed using a portable pH, conductivity multi-parameter meter (HQ40d, HACH, USA).

Chemical analyses

Total Hardness (TH) was calculated by titration method. Nitrate (mg/L No^3) and fluoride (F^-) ions were specified using the spectrophotometer (DR600). The optimum fluoride concentration for a society may be determined by obtaining the mean maximum temperature. It was determined by the following formula: Optimal Fluoride Concentration (mg/L) = $0.022 / 0.0104 + 0.000724 \times \text{AMMT}$.

Where AMMT is the Annual Mean Maximum Temperature in selected cities. Total organic carbon (TOC) was determined by catalytic combustion catalytic oxidation using an online TOC analyzer (VCSH- Shimadzu).

Microbiological analyses

The Total Fecal Coliform Count ((TCC) and (FCC)) were analyzed by the most probable number (MPN) method. The

heterotrophic plate count (HPC) by pour plating method was used to examine the bacterial count in POU-WT systems [15].

Statistical analysis

One-way analysis of variances (ANOVA) was performed to the experimental values comparison in selected cities with each other and the national and international guideline. The presumption of normality of data was confirmed with the One-Sample Kolmogorov-Smirnov Test. All the statistical analyses were performed using SPSS 16.0, and a *p* value of less than 0.05 represents a significant difference between groups (confidence level 95%).

Results

Questionnaires and face-to-face interviews

The results of the questionnaire about consumer knowledge of POU-WT systems were found that most of POU-WT systems users (86%) complained about tap water hardness, and all of them believed that high content of solids in water will lead to diseases such as stone formation in bladder and kidney, and blocked arteries. These systems were introduced to the 72% of users through advertisements and the social media (Fig. 2). Information levels of 64% of POU-WT systems users about the treatment process and operational principles of the device were not reasonable (Fig. 2). These systems were installed by sellers and brief information and in most cases, non-scientific and non-documentary will be offered to customers. Judgment about the performance of POU-WT systems by users was based on the taste of treated water and creating sediment in the kettle. Only in one of the Brands of POU-WT systems had conducted the quality test for performance of the device. Period of time for cleaning and replacing of POU-WT systems filters and membranes in Tehran and Rasht was between 6 months to a year while in Ahvaz this period was less time (replacing the first phase filter was sometimes less than a month). None of the users were aware of biofilm formation and bacterial regrowth in the filter of POU-WT systems.

Overall satisfaction of 72% of users was great with support services provided by sellers.

Physical and chemical properties

Figure 3 indicates pH variations in three selected brands of POU-WT systems' (input and output) at studied cities. The pH variations of input in Tehran, Rasht, and Ahvaz were in the range of 7.65–7.75, 6.50–7, and 7.28, respectively. Based on the pH results, it can be stated that all samples of input had permissible levels [2, 17]. pH variations of output reduced in all of the samples (the lowest in Rasht(5.70)). The EC variation of input in Tehran, Rasht, and Ahvaz was 483–503, 445–450 and 1443.5 $\mu\text{S}/\text{cm}$, respectively (Fig. 3). The findings showed that the values of EC in all samples of output were lower than 60 $\mu\text{S}/\text{cm}$. The maximum water hardness in the input of Tehran, Rasht, and Ahvaz was found as 166.5, 287.5, and 210 mg/L as CaCO_3 respectively, were within the admissible limits [17]. For output of POU-WT, the findings showed that the values of water hardness in all samples were lower 52.5 mg/L as CaCO_3 (Fig. 4). According to the Fig. 4, the maximum levels of Nitrate in the input were 16.3, 5, and 1.8 mg/L NO_3 , respectively for Tehran, Rasht, and Ahvaz which reached 4.8, 1.5, and 0.4 mg/L in the output water, respectively. Based on the figure, the levels of Nitrate in input and output POU-WT systems were lower than the maximum contaminant level (50 mg/L NO_3) which is proposed by WHO [2]. The range of nitrate in Tehran was the highest value.

Figure 5 shows the concentration of fluoride in three studied cities in the input and output of POU-WT. WHO and also ISIRI have set an admissible contaminant value for fluoride in drinking water. As can be seen in the figure, the maximum of fluoride in the input was 0.38, 0.33, and 0.51 mg/L respectively for Tehran, Rasht, and Ahvaz. Among these, all samples of brands had the concentrations which were below admissible levels [2, 17]. Furthermore, the fluoride level in the Ahvaz was the highest. The results revealed that the maximum of Total Organic Carbon (TOC) were 0.24 and 0.12, and 1.69 mg/L for Tehran, Rasht, and Ahvaz (Fig. 5) WHO and ISIRI have not set a guideline for TOC in DW. The output of brands in the city of Ahvaz was higher than two studied cities.

Fig. 2 Awareness levels POU-WT systems users (a) and Brand Selection method (b)

Fig. 3 The Range of physical and chemical parameters variations in POU-WT water samples in selected cities: A- pH, B-EC

Microbial quality

HPC level of the samples was summarized in Fig. 6. ISIRI proposed a 100 CFU/mL MCL for HPC count in the desalinated drinking water in industrial and household systems [18]. However, as seen in the figure, the maximum values of HPC in the input of brands in Tehran, Rasht, and Ahvaz were 5, 4, and 44 CFU/mL, respectively, which reached 593, 542 and 700 CFU/mL at the output. Furthermore, the results showed that the level of MPN indexing microbiological tests (total coliform and fecal coliform) in 360 water sample (input and output of POU-WT system) were negative for three cities.

Comparative analysis

The statistical analysis of the results of input and output of POU-WT systems in Tehran, Rasht, and Ahvaz was summarized in Tables 1 and 2, respectively. The one-way analysis of variance (ANOVA) for the input and output of POU-WT systems indicated that except EC and Total Hardness (TH) of output, the mean levels of all parameters are different in selected cities ($p < 0.05$). The quality of the tested waters was compared to WHO, EPA, and ISIRI guidelines. There is no significant difference between the value of parameters in the input of POU-WT and the above-mentioned guidelines.

Fig. 4 Range of physical and chemical parameters variations in POU-WT water samples in selected cities; A- Hardness, B- Nitrate

Discussion

The pH level of drinking water shows the power of an acidic or basic character [19]. It is difficult to clarify any obvious relationship between human health and the drinking water pH. The water with a pH < 6.5 can be acidic, clearly soft, and corrosive. Acidic water may cause aesthetic problems, such as a metallic or bitter taste and can also be corrosive to metal pipes, thereby releasing harmful metals such as copper, lead, etc. The potable water pH will shift depending on the substance and distribution system parts [20]. A health-based guideline value for pH has not been advised by WHO, while in US-EPA standard pH considered in the table of secondary drinking water standards putting a maximum contaminant level (MCL) value limited between 6.5 and 8.5 [21]. Based on Fig. 3, the level of input pH was within the admissible limit of ISIRI and also EPA guidelines [2, 21], which is decreased in all of the brands' output in selected cities. Therefore, it can be concluded that using the RO process led to pH reduction and

ultimately to the health problems. Tables 1 and 2 showed that there is a significant difference ($p < 0.001$) between the selected cities in term of mean pH of the input and output of POU-WT systems. In Yari et al. study, none of the selected POU-WT systems didn't meet the admissible limit [22]. In another similar study, all samples of output had pH value within the admissible limit of ISIRI [23]. In addition, the results of a research on quality of water extracted from desalination facilities in cities and villages of Iran showed that pH of POU systems' output tended toward acidity and corrosion.

Electrical Conductivity (EC) is the measure of the ability of water to conduct electrical current. This capacity depends on the concentration of ions, ionic mobility, and temperature. The EC of water directly related to its total dissolved solids content [24]. The range of EC values in the different POU-WT inputs in studied cities was observed from 445 to 1443.5 $\mu\text{S}/\text{cm}$. The results revealed that the levels of EC in Ahvaz were the highest value. All of the POU-WT water samples have EC value below 60 $\mu\text{S}/\text{cm}$ and the samples output in B1 showed the lowest value

Fig. 5 The Range of Physical and chemical parameters variations in POU-WT water samples in selected cities; A- Fluoride, B-TOC

(Fig. 3). We don't have any guideline value for EC by WHO and ISIRI, while European Union (EU) is considered 400–1000 $\mu\text{S}/\text{cm}$ for desirable drinking water [25]. It is noted that inputs of all POU-WT systems were in the limited level except Ahvaz (1307 ± 59.8). While all samples of output were lower than the minimum permissible limit. The results of EC value in water samples of POU-WT in Qom have indicated 99–1590 $\mu\text{S}/\text{cm}$, while 47% of the EC value was less than 400 $\mu\text{S}/\text{cm}$ mean EC value in input of POU-WT systems was Less than the significant level ($p < 0.05$), while output was not significant.

The water Hardness Classified, according to WHO in 2004 [26]. Based on the classification and Fig. 4, input water of Tehran was Moderate Hard and Rasht and Ahvaz belonged in the hard category, while the all samples of output from

POU-WT systems were in soft category of hardness levels. There are not a sufficiently strong evidence to the relation between total hardness (TH) in drinking water and harmful health consequences in humans [1]. In the opposite, there is an adverse correlation between the TH in drinking water and cardiovascular diseases (CVDs) [27, 28]. Some surveys offer that drinking water with a TH of below 75 mg/L may have a bad efficacy on mineral balance [1]. The results of this study agreed on these findings. According to Fahiminia et al. results, the average concentration of magnesium, calcium, total hardness and fluoride of the samples were 0.9, 5.7, 60 and 0.05 mg/L respectively [12] which regarding to the TH standard (above 500 mg/L in DW) is considered to be aesthetically unsuitable [29].

Fig. 6 The Range of HPC parameter variations in POU water samples in selected cities

The use of high nitrate value drinking water may enhance the hazard of cancer in adults and methemoglobinemia in infants or young children [30]. The levels, which were allowed by the WHO, ISIRI, for nitrate in drinking water is 50 mg/L as nitrate ion [1, 2]. Based on Fig. 4, the levels of nitrate in the input and output of all brands were lower than ISIRI [2], the highest level of nitrate inputs (13.75 ± 5.2) was reported in Tehran, also the all of selected brands' output in the three studied cities was significantly reduced, which were inconsistent with the Verma et al. results [31]. There is a significant difference ($p < 0.05$) between the selected cities in term of mean nitrate of the input and output of POU-WT systems (Tables 1 and 2).

Water fluoridation is noticed as one of the most efficacious processes in the decrease of dental caries on the social health

level and its greatest impact on publicly care of children with higher outbreak of tooth decay [32]. WHO has recognized dental caries as a global epidemic and also suggested to enhance fluoride to DW, which has less than optimal fluoride levels [33]. The optimal fluoride levels of ISIRI are between 0.5–1.5 mg/L. In the present study (Fig. 4), the highest level of fluoride ions in the output of POU systems samples were 0.26 mg/L in Ahvaz. The fluoride level in Tehran and Rasht was about zero which significantly was lower than the regulatory limit of WHO and ISIRI permissible limit [2]. This result is inconsistent with Miranzadeh et al. results [34]. According to Tables 1 and 2, The POU-WT fluoride's of input and output are significantly different ($p < 0.05$) in studied cities.

TOC in drinking water is a medium for the formation of disinfection by-products (DBP). Drinking water containing

Table 1 Descriptive analysis of physical, chemical and microbial quality of POU input water in selected cities

Cities		Parameters						
		pH	EC ($\mu\text{S}/\text{cm}$)	TH (mg/L ac CaCO_3)	Nitrate (mg/L NO_3)	Fluoride (mg/L)	TOC (mg/L)	HPC (CFU/mL)
Tehran	Min	7.39	423	145	5.2	0.24	0.1	0
	Max	7.84	527	184.5	38	0.44	0.38	5
	Mean	7.68	493	164.4	13.75	0.33	0.22	3
	SD	0.077	17.22	9.51	5.2	0.044	0.13	2.64
Rasht	Min	6.50	422	252	3.4	0.18	0.09	0
	Max	7.36	493	296	5.6	0.43	0.12	4
	Mean	6.77	455	245.7	4.66	0.29	0.11	2
	SD	0.026	14.89	10.75	0.51	0.049	0.01	2
Ahvaz	Min	7.23	1307	145	1.5	0.49	1.64	44
	Max	7.31	1552	295	1.75	0.51	1.74	4
	Mean	7.27	1437	217.5	1.70	0.50	1.69	43
	SD	0.016	59.8	3.68	0.12	0.004	0.05	21.4
p value		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 2 Descriptive analysis of physical and chemical and microbial quality of POU output water in selected cities

Cities		Parameters						
		pH	EC ($\mu\text{S}/\text{cm}$)	TH (mg/L ac CaCO_3)	Nitrate (mg/L)	Fluoride (mg/L)	TOC (mg/L)	HPC (CFU/mL)
Tehran	Min	6.6	27	19	1.2	0	0.02	510
	Max	7.6	84	53	8.4	0.05	0.1	593
	Mean	7.2	49.8	33	4.5	0.02	0.05	543
	SD	0.42	26.7	12.8	2.4	0.02	0.03	43.84
Rasht	Min	5.6	38	10.2	0	0	0.05	538
	Max	6.5	67	60	1.33	0.03	0.08	582
	Mean	6.05	49.8	34.5	0.98	0.01	0.06	554
	SD	0.33	11.6	16.7	0.52	0.01	0.01	24.33
Ahvaz	Min	6.1	31	3.3	0.33	0.2	0.2	650
	Max	7.5	97	65	0.93	0.27	1.59	700
	Mean	6.7	58.17	41.5	0.52	0.23	0.83	676
	SD	0.54	28.4	22.5	0.22	0.02	0.51	25.17
p value		< 0.001	0.78	0.68	< 0.001	< 0.001	< 0.001	< 0.001

DBP in excess of the limit may lead to adverse health effects, liver, or kidney problems, or nervous system effects, and may lead to increase the risk of getting cancer [35]. As can be seen in Fig. 5, the highest level of the input TOC was in Ahvaz with 1.69 ± 0.05 mg/L, while The TOC value of output of the POU-WT water in all cities are fewer than 0.15 mg/L (Fig. 5). Therefore, the DPB formation in the presence of chlorine is very low. The TOC of input and output samples in POU-WT systems are significantly lower ($p < 0.05$) in studied cities.

The microbiological quality characteristic of the POU-WT systems in selected cities was assessed using the HPC and MPN indexing [36]. An increased HPC count in drinking water does not represent a remarkable health risk, and no health-based guideline is recommended so far [37]. ISIRI proposed an MCL of 100 CFU/mL for HPC count in desalinated drinking water in industrial and household systems [38]. The input of POU-WT studied in the Ahvaz with the level of 44 ± 21.4 CFU/mL was in the highest value (Fig. 6). The HPC counts confirmed an increase the level of heterotrophic bacteria in the output water of all brands (Above 510 CFU/mL), which is higher values than ISIRI limit [38]. It was reported that High value of HPC in some samples indicates the potential for microbial growth and contamination Storage of treated water [13]. These findings have met the ISIRI and also WHO guidelines for drinking water. POU-WT HPC's of input and output are significantly different ($p < 0.05$) in studied cities. The number of total and fecal coliforms were negative in all inputs and outputs in Tehran, Rasht, and Ahvaz indicated that these microorganisms were absent in the studied POU-WT systems (Table 1). The results of Khodadadi et al. study showed that some parameters in output water were as follows: TDS = 262–369 mg/l, total hardness = 92–200 mg/L as CaCO_3 , nitrate = 4.31–11 mg/L Ca = 6.4–12.8 mg/L, Mg =

17.3–40.3 mg/L, pH range = 7–7.6, fecal coliform = 0 (MPN/100), total coliform = 0 (MPN/100), EC = 403.4–507.7 $\mu\text{S}/\text{cm}$ [23].

Conclusion

This paper has highlighted an evaluation of three different POU-WT systems' brands accessible for Tehran, Rasht, and Ahvaz consumers. The finding data was compared with the quality of tap waters and regulatory from WHO, US-EPA and ISIRI. It is shown that the quality of tap water in three studied cities (except EC value in Ahvaz) is either lower or meets the national and international standards, and it is not a risk to consumer's health. Based on our findings, due to the different water quality in each city ($p < 0.05$), the output of each brand also varied. In general, the POU-WT systems in three cities eliminated useful minerals such as calcium, magnesium, fluoride, and increasing the growth of heterotrophic bacteria, hence the long-term usage of them not only causes health promotion but also causes adverse effects on human health. Finally, before installing RO-based POU-WT systems, it is not able to know the primary quality of the tap water and to detect a balance between the potential advantages of these systems and the potentially harmful effects of declining the mineral's amount. It is proposed since reverse osmosis (RO) is not especially beneficial to a nutritional viewpoint; RO-based POU-WT is used particularly when it is suitable to eliminate inorganic chemicals of potential concern, such as nitrate. In conclusion, the use of RO-based POU-WT systems in cities with similar tap water quality in the present study is not extremely suggested, especially if the systems are not constantly and properly maintained and operation by the specifically proficient people. Considering the Rasht and EC value water

hardness and hardness of Ahvaz which are more than the desirable level, in the current situation it is recommended to use the softening systems instead of RO-based POU-WT systems.

Acknowledgments The present article has been financially supported by Center for Water Quality Research, Institute for Environmental Research, Tehran University of Medical Sciences, with Research code No. of 29230. The authors would like to sincerely thank Iran University of Medical Sciences and Ahvaz Jundishapur University of Medical Sciences for their cooperation.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interests.

References

- Organization WH. Guidelines for drinking-water quality: World Health Organization; 2004.
- Edition F. Guidelines for drinking-water quality. WHO chronicle. 2011;38:104–8.
- Do AT, Kuroda K, Hayashi T, Nga TTV, Oguma K, Takizawa S. Household survey of installation and treatment efficiency of point-of-use water treatment systems in Hanoi, Vietnam. *J Water Supply Res Technol AQUA*. 2014;63(2):154–61.
- Varol S, Davraz A. Evaluation of potential human health risk and investigation of drinking water quality in Isparta city center (Turkey). *J Water Health*. 2016;14(3):471–88.
- Bolaji B, Bolaji G, Ismaila S. Performance evaluation of a locally developed domestic drinking water filter. *Int J Environ Stud*. 2010;67(5):763–71.
- Dindarloo K, Ghaffari HR, Kheradpisheh Z, Alipour V, Ghanbarnejad A, Fakhri Y, et al. Drinking water quality: comparative study of tap water, drinking bottled water and point of use (PoU) treated water in Bandar-e-Abbas, Iran. *Desalin Water Treat*. 2016;57(10):4487–93.
- Chaidez C, Gerba CP. Comparison of the microbiologic quality of point-of-use (POU)-treated water and tap water. *Int J Environ Health Res*. 2004;14(4):253–60.
- Ebrahimi SM, Shiri Z, Mosavi SM, Memar MY. Bacteriological quality of water produced by household water treatment devices. *Journal of Mazandaran University of Medical Sciences*. 2015;25(130):8–18.
- Peter-Varbanets M, Zurbrugg C, Swartz C, Pronk W. Decentralized systems for potable water and the potential of membrane technology. *Water Res*. 2009;43(2):245–65.
- Sacchetti R, De Luca G, Dormi A, Guberti E, Zanetti F. Microbial quality of drinking water from microfiltered water dispensers. *Int J Hyg Environ Health*. 2014;217(2):255–9.
- Zanetti F, De Luca G, Sacchetti R. Control of bacterial contamination in microfiltered water dispensers (MWDs) by disinfection. *Int J Food Microbiol*. 2009;128(3):446–52.
- Fahiminia M, Mosafieri M, Taadi RA, Pourakbar M. Evaluation of point-of-use drinking water treatment systems' performance and problems. *Desalin Water Treat*. 2014;52(10–12):1855–64.
- Al-Haddad A, Al-Qallaf H, Rashid T. Effectiveness of domestic water filters. *Desalin Water Treat*. 2015;53(3):649–57.
- Anumol T, Clarke BO, Merel S, Snyder SA. Point-of-use devices for attenuation of trace organic compounds in water. *Journal: American Water Works Association*. 2015;107(9).
- Federation WE, Association A. Standard methods for the examination of water and wastewater. American public health association (APHA). Washington, DC: USA; 2005.
- Safari Y, Asadi F, Amiri N, Motlagh ZJ, Azari A, Sharafi H, et al. Management of drinking water consumption at home: a case study of knowledge and attitude evaluation-Kermanshah, Iran (2015). *Executive Editor*. 2403;8(2):2017.
- Iranian Institute of Standard and Industrial Researches (IISIR). Drinking water characteristics. In: Fifth ed.; 2010.
- Organization INS. Desalinated drinking water in industrial and households systems-Micobial specifications. 2016.
- Shehzadi R, Rafique H, Abbas I, Sohl MA, Ramay SM, Mahmood A, et al. Assessment of drinking water quality of tehsil Alipur, Pakistan. *Desalin Water Treat*. 2015;55(8):2253–64.
- Fawell J. pH in drinking-water. Revised background document for development of WHO guidelines for drinking-water quality. Geneva: World Health Organization; 2007.
- U.S. Environmental Protection Agency Secondary Drinking Water Standards: Guidance for Nuisance Chemicals [database on the Internet]. Available from: <https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals>.
- Yari A, Safdari M, Hadadian L, Babakhani M. The physical, chemical and microbial quality of treated water in Qom s desalination plants. 2007.
- Khodadadi M, Mahvi A, Ghaneian M, Ehrampoush M, Dorri H, Rafati L. The role of desalination in removal of the chemical, physical and biological parameters of drinking water (a case study of Birjand City, Iran). *Desalin Water Treat*. 2016;57(53):25331–6.
- van der Aa M. Classification of mineral water types and comparison with drinking water standards. *Environ Geol*. 2003;44(5):554–63.
- Lucentini L, Pettine P, Stottmeister E, Menichini E. Chemical analysis of the quality of water for human consumption: proposal for the revision of the performance requirements in the drinking water directive 98/83/EC. *TrAC Trends Anal Chem*. 2013;45:37–47. <https://doi.org/10.1016/j.trac.2012.12.014>.
- Selvam S, Manimaran G, Sivasubramanian P, Balasubramanian N, Seshunarayana T. GIS-based evaluation of water quality index of groundwater resources around Tuticorin coastal city, South India. *Environmental earth sciences*. 2014;71(6):2847–67.
- Dzik A. Cerebrovascular disease mortality rates and water hardness in North Dakota. *S D J Med*. 1989;42(4):5–7.
- Momeni M, Gharedaghi Z, Amin MM, Poursafa P, Mansourian M. Does water hardness have preventive effect on cardiovascular disease? *Int J Prev Med*. 2014;5(2):159–63.
- Zoeteman BC. Sensory assessment of water quality: Pergamon series on environmental science: Elsevier; 2015.
- Richard AM, Diaz JH, Kaye AD. Reexamining the risks of drinking-water nitrates on public health. *Ochsner J*. 2014;14(3):392–8.
- Verma AK, Saksena D. A Review on various Point of Use-Drinking Water Purification Technologies.
- Jeri BA. The fluoride concentration of bottled drinking water in Al-Basra City, Iraq. *Journal of Baghdad College of Dentistry*. 2016;28(1):143–6.
- Somasundaram S, Ravi K, Rajapandian K, Gurunathan D. Fluoride content of bottled drinking water in Chennai, Tamilnadu. *J Clin Diagn Res*. 2015;9(10):ZC32–4.
- Miranzadeh MB, Rabbani DK. Chemical quality evaluation for the inlet and outlet water taken from of the desalination plants utilized

- in Kashan during 2008. *KAUMS Journal (FEYZ)*. 2010;14(2): 120–5.
35. Florentin A, Hautemanière A, Hartemann P. Health effects of disinfection by-products in chlorinated swimming pools. *Int J Hyg Environ Health*. 2011;214(6):461–9.
 36. Pindi PK, Yadav PR, Kodaparthi A. Bacteriological and physico-chemical quality of main drinking water sources. *Pol J Environ Stud*. 2013;22:825–30.
 37. Diduch M, Polkowska Ż, Namieśnik J. The role of heterotrophic plate count bacteria in bottled water quality assessment. *Food Control*. 2016;61:188–95.
 38. Iranian National Standardization Organization, Desalinated drinking water in industrial and households systems- Microbial specifications, 2016.