Are Household Water Purification Devices Useful to Improve the Physical Chemical and Microbial Quality of the Feed Water? Case Study: Bandar Abbas South of Iran

[1]Vali Alipour, [2]Mohammad Mehdi Baneshi, [3]Somayeh Rahdar, [4]Mohammad Reza
Narooie, [5]Arsalan Salimi, [6]Razieh Khaksefidi, [7]Mehdi Saeidi, [8]Morteza Ahamadabadi and [9]Hamed Biglari
[1]Department of Environmental Health Engineering,
Research Center for Social Determinants in Health Promotion, School of Public Health,
Hormozgan University of Medical Sciences, Bandar Abbas, Iran
[2]Social Determinants of Health Research Center, Yasuj University of Medical Science, Yasuj, Iran
[3]Department of Environmental Health Engineering, School of Public Health,
Zabol University of Medical Sciences, Zabol, Iran
[4]Department of Environmental Health Engineering, School of Public Health,
Iranshahr University of Medical Sciences, Iranshahr, Iran
[5]Research Center for Environmental Determinants of Health,
Kermanshah University of Medical Sciences, Kermanshah, Iran
[6]Department of Environmental Health Engineering, School of Public Health,
Zahedan University of Medical Science, Zahedan, Iran
[7]Department of Environmental Health Engineering School of Health,
Torbat Heydariyeh University of Medical Sciences, Torbat Heydariyeh, Iran
[8]Department of Environmental Health Engineering,
Torbat jam Faculty of Medical sciences, Torbat jam, Iran
[9]Department of Environmental Health Engineering,
Social Development and Health Promotion Research Center, School of Public Health,
Gonabad University of Medical Sciences, Gonabad, Iran

Abstract: part of the bandar abbas population in southern Iran, in order to access to better water quality than municipal tap water systems, use household water purification devices. The aim of this study was to determine to what extent these devices are effective in improving the quality and the efficiency are desirable for the production of water quality. This cross-sectional study that was conducted in a six-month period time in 2015 in Bandar Abbas. A total of 30 samples of water from various home water purification apparatuses were sampled and tested for hardness, alkalinity, pH, Total Dissolved Solids (TDS) and Electrical Conductivity (EC), turbidity and MPN was performed on the samples. Statistical analysis was performed using SPSS version 19 and statistical tests ANOVA and Pearson correlation test. The efficiency of the apparatuses to reduce turbidity, hardness, alkalinity, Na, K and Cl, respectively were 45.9, 39, 22.3, 30.6, 34.9 and 53% and in reduce of TDS and EC respectively were 37.5 and 59 %. The devices ability to change the pH of water was low and negative (-5.8 %). In 26.6% of influent samples, microbial contamination was detected which in all mentioned cases, the microbial contaminated were showed in effluent samples. In general, the use of these devices were not necessarily lead to improved water quality. After working the 12-month period significantly decreased efficiency. The number of treatment stages did not impact in device efficiency improvement.

Key words: Water treatment, purification devices, water quality, chemical quality, improvement

INTRODUCTION

According to the World Health Organization report, more than a billion people worldwide lack access to safe drinking water (Alipour *et al.*, 2015). A number of patients and deaths occur per year as a result of contaminated water (Mirzabeygi *et al.*, 2016; Souter *et al.*, 2003; Dunk *et al.*, 2005). Concern about health risk related to

Corresponding Author: Hamed Biglari, Department of Environmental Health Engineering, School of Public Health,
Social Development and Health Promotion Research Center, Gonabad University of Medical Sciences,
Gonabad, Iran

water and advertising messages about Household water treatment devices leading to use of these apparatuses in many areas. Household Water Purification Apparatuses (HWPA) are classified in point of use treatment systems (Ren and Smith, 2013; Bazrafshan *et al.*, 2012a, b; Biglari *et al.*, 2016), these devices generally include activated carbon filters, membrane filters and ion exchange, distillation and disinfection UV systems (Sobsey *et al.*, 2008, Biglari *et al.*, 2016). The past surveys showed that HWPA can be useful only in the area with polluted water while many of user's implements HWPA as a means of fantasy instrument without information about the suitable condition for use (Smieja, 2011). The use of HWPA requires extensive research on effluent water quality from HWPA. HWPA should be selected based on the quality of water entering the system, the quality of the output device and the refined mechanism (Hunter, 2009). HWPA are in a variety of three-step, five-step, six and 11-stage HWPA on the market. Six treatment stages used in three to six stages HWPA are provided in the following (Abebe *et al.*, 2015). In eleven stages devices, a ceramic filter and several different stage sand filter have been added to the previous six stages (14). The first step is the ion exchange resins that reduces water hardness via transformation of dissolved calcium and magnesium ions in water to insoluble forms. These resins are very conducive environment to growth and reproduction of bacteria inside the filter in the shortest time so that the number of bacteria increases significantly (Biglari *et al.*, 2016b). Second units are activated carbon filters which have high ability to remove odor and unpleasant taste as well as the efficiently remove residual chlorine from drinking water. The third stage are fabric filters (1 and 5 microns) that made of polypropylene fibers. The performance of the filters is exactly like a strainer so that particulate matter such as mud, sand, rust particles produced by decaying pipes and piping network and other suspended matters are removed from the water. Step Four are Zeolites; natural resins that have properties of exchange for cations (arsenic, titanium, aluminum, cobalt, chromium, aluminum, lead, zinc and so on) and heavy metals. Step five is ceramic filters with pore size of 0.5 microns that act as a barrier for suspended materials and all the parasites and some of bacteria while water passes (Craver and Smith, 2007; Biglari *et al.*, 2016c, d). Step Six is reverse osmosis and Nano-filtration membranes that are used to separate ions and macromolecules from the water. The importance of the membranes is removal of specific contaminants such as THMs, pesticides, natural organic matter, nutrients and water softening (Enger *et al.*, 2013; Peter-Varbanets *et al.*, 2009; Sajjadi *et al.*, 2016; Mohammadi *et al.*, 2015). Several studies have been conducted on this topic around the world, including

(Willis *et al*, 2013), (Mintz *et al.*, 2001), Mwabi in Africa (Mwabi *et al.*, 2011). A similar study was done in other parts of the country. In a fahimnia study entitled evaluation of point-of-use drinking water treatment systems performance and problems, the results showed that the device can reduce the TDS of water to 90% and aluminum to 5% and cadmium to 86% (Fahiminia *et al.*, 2014). Bandar Abbas (BA) with 45 km^2 and 650000 inhabitants, center of Hormozgan province is located in southern Iran. The weather of BA is Hot and humid weather; so this summer in the city was so close to nine months. The water demand of BA is about 150,000 cubic meters per day which much of the drinking water of Bandar Abbas (95%) will be supplied from the Esteghlal Dam reservoir. Bandar drinking water meet all of water primary standards. However, due to the no desirable taste and odor (mostly in summer and autumn) water quality is not accepted by users, so it leads to dissatisfaction of the city's water quality (Mousazadeh, 2013) which is why a large percentage of the people of this city use household water treatment devices to access suitable water quality. The aim of this study was to evaluate the efficiency of the household water treatment apparatus in production a suitable water quality.

MATERIALS AND METHODS

In this descriptive-analytic study which was conducted in 2016 in the city of Bandar Abbas, according to the diversity of the number of HWPAs, random cluster method was used for sampling. Any type of HWPA considered as a cluster and they were randomly sampled. To calculate the sample size the average of total hardness produced water was assumed in range of 81-105 mg L^{-1} as CaCO$_3$; considering the standard deviation of 6, by using the Eq 1, the sample size was determined as 30 samples. Hardness testing using titration methods (Merck materials, expire date to end of 2017) and in accordance with standard procedure reference number C 2340 of standard methods were performed. Alkalinity by titration methods, using materials manufactured by merck and Scharlau companies (date expires until the end of 2017) and in accordance with standard procedure reference number B 2320 of standard method was tested (APHA, 1915). To measuring TDS and EC, TDS meter of Aqua lytic (model of CD24, Italy) with accuracy of 0.01 units and to turbidity measurement by a Hach 2100N Laboratory Turbid meter (Hatch Ltd., USA) were used. pH was measured using Elmetron pH meter (model of CP-501) and to evaluate the microbial quality of water, the Most Probable Number (MPN) technique was used based on

standard methods procedure. Statistical analysis was conducted using SPSS Software version of 19 for windows and the tests of ANOVA and Pierson correlation were used and p-value <0.05 was purposed as significant level:

$$Eq. 1 \rightarrow n = \frac{z_{\alpha/2}^2 \times \sigma^2}{d^2}$$

RESULTS AND DISCUSSION

The done tests on 30 samples taken from different apparatus were classified in four clusters as (eleven, six, five and three unit stages) then analyzed. Results of measured qualitative parameters in influent and effluent of devices as mean values are presented in Table 1. The purpose of this table showing the overall status of

Table 1: Average measured values of influent and effluent of water taken from water purification systems under the study

Parameter	Unit	Influent	Effluent
Turbidity	NTU	0.61±0.29	0.33±0.12
Hardness	mg L^{-1} as CaCO$_3$	269.30±135.13	124.27±72.70
TDS	mg L^{-1}	958.90±103.78	469.44±141.07
NA	mg L^{-1}	12.74±1.98	7.04±2.05
K	mg L^{-1}	8.81±1.93	4.73±1.71
CL	mg L^{-1}	164.42±20.91	57.43±23.65
ALK	mg L^{-1} as CaCO$_3$	204.11±21.98	128.60±22.63
EC	μ S/cm	1292.51±86.27	409.53±205.76
PH	-	7.27 ±0.39	7.69±0.26

influent and effluent of water quality related to studied HWPAs. In order to illustration the effect of unit number in HWPAs on efficiency of them in reducing the measured parameter, Fig. 1 and 2 is presented. Turbidity of input and output of all devices was in the standard range; less than NTU1. Among studied HWPAs, the type of 3 stages apparatus had the maximum efficiency in the removal of turbidity. The most performance for turbidity reduction was observed after 6 months in-line duration and after that the efficiency showed a continued downward trend. The TDS in output water of all devices was less than standard. TDS is less than desirable in a number of devices by reducing TDS of water decreases the quality of water. Eleven-stage apparatus showed the most efficiency to reduce TDS. In all devices slight decrease occurred in the alkalinity (<25%). A large number of households in different cities of Iran, use of HWPA. Most users of HWPA, unaware of its true performance and what they know about the quality of the device is on the basis of advertising information. Some of these devices, not meet the standard water quality so they produce the water same as public water quality and even in some cases lower than that. Some of the devices also reduce many of the minerals which are needed for human body. According to research conducted in areas where water
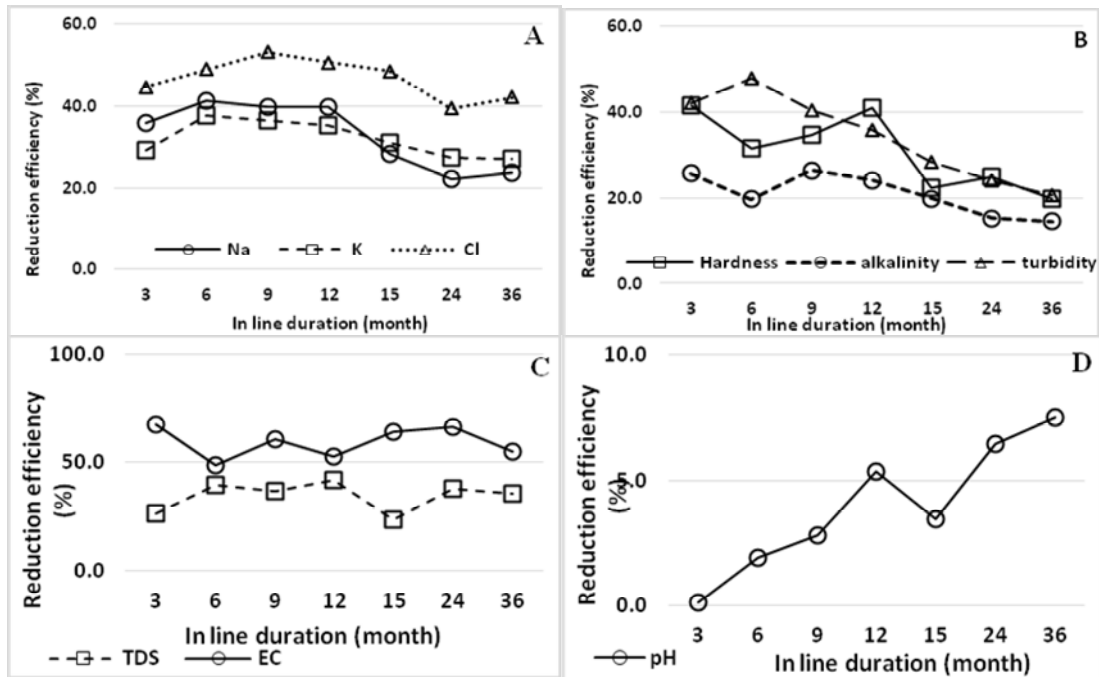

Fig. 1: The relationship between in-line duration of household water purification devices to efficiency in reducing Na, Cl and K (A), hardness and alkalinity (B), EC and TDS (C) and pH (D)
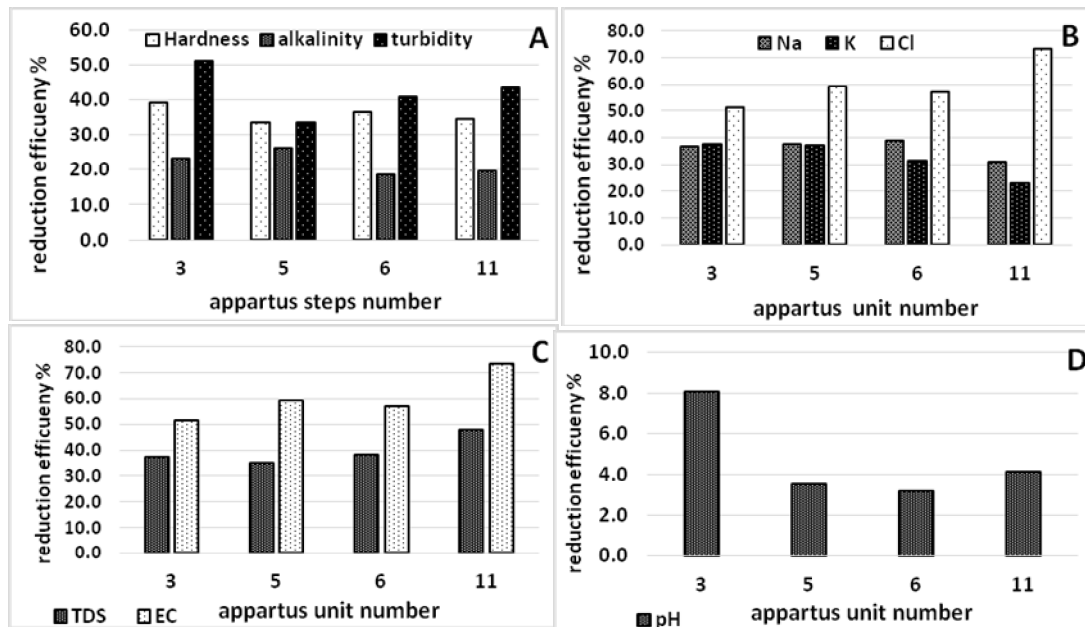
Fig. 2: The relationship between number of treatment units of HWPAs to efficiency in reducing Na, Cl and K (A), hardness and alkalinity (B), EC and TDS(C) and pH (D)

hardness is high, cardiovascular patients is low (Momeni *et al.*, 2014). Optimal water hardness range is from 75-150 mg/L as $CaCO_3$ which called semi-hard water. However, in some devices there has been a sharp decrease in water hardness output that can be inappropriate. All the apparatuses, similar efficiency in the reduction of hardness so significant differences between them were not approved by ANOVA analysis (p = 0.081). According to the results, in 26.6% of influent samples, microbial contamination was detected which in all mentioned cases, the microbial contaminated were showed in effluent samples. It means that the house hold water purification devices in each case have failed to reduce the contamination. Hence, these devices had not suitable efficiency in reducing microbial. Pierson correlation analysis was done to determining the correlation between in-line duration and reduction efficiency for different parameters which showed; there is a significant negative correlation between in-line duration and parameters of alkalinity, turbidity, K and Na and the related coefficients were as (r = -0.427, p = 0.006), (r = -0.606, p = 0.003), (r = -0.353, p = 0.009) and (r = -0.289, p = 0.007) respectively. It means that by increasing the in-line duration, the efficiency of apparatuses showed a significant reduction. There was not a significant correlation between the in-line duration and the devices efficiency in reduction of Cl, TDS, EC and pH; the related coefficient respectively w ere as (r = -0.002, p = 0.083), (r = -0.052, p = 0.061),

(r = -0.004, p = 0.092) and (r = -0.011, p = 0.071) which means the index of in-line duration is not played a uniform and significant role on apparatuses performance to reduction the last mentioned parameters. The same statistical analysis was done for determining the relationship between the number of apparatus units and their efficiency on studied parameter reduction from influent to effluent; This analysis were not approved correlations for turbidity index (r = 0.003, p = 0.091). Pearson correlation test did not show the correlation between hardness and alkalinity reduction efficiency with the steps number of the devices; correlation coefficient respectively were as (r = 0.007, p = 0.068) and (r = 0.003, p = 0.091). In the case of electrical conductivity and total dissolved salts, there were little correlation coefficients; (r = 0.038, p = 0.042) and (r = 0.022, p = 0.038) respectively. This condition implies that the number of units in different household devices has not significant impact in improving water quality. Given the importance of microbial water quality, it is essential to the accurate maintenance of water treatment systems, so these devices have to install in clean places and in places like the nearby sewage systems, sinks and the like are not installed.

CONCLUSION

Much of the Claimed material about the performance of HWPAs are the advertising material, so in numerous cases the HWPAs have not been completely desirable

performance; especially in the case of microbial contamination, the HWPAs have very low efficiency and even in some cases have increased microbial contamination of water. In the operation of HWPAs, should be applied carefully; so after a 12-month period of performance, the apparatuses efficiency significantly reduced and the process further over time, faster. Therefore, it is advisable to do after the end of this period of operation; device service should be done. The number of treatment steps in commercial devices available on the market had not a significant role in improving the efficiency of such devices.

REFERENCES

APHA., 1915. Standard methods for the examination of water and wastewater. American Public Health Association, USA.

Abebe, L.S., Y.H. Su, R.L. Guerrant, N.S. Swami and J.A. Smith, 2015. Point-of-use removal of Cryptosporidium parvum from water: Independent effects of disinfection by silver nanoparticles and silver ions and by physical filtration in ceramic porous media. Environ. Sci. Technol., 49: 12958-12967.

Alipour, V., A.H. Mahvi and L. Rezaei, 2015. Quantitative and qualitative characteristics of condensate water of home air-conditioning system in Iran. Desalin. Water Treat., 53: 1834-1839.

Bazrafshan, E., H. Biglari and A.H. Mahvi, 2012a. Phenol removal by electrocoagulation process from aqueous solutions. Fresenius Environ. Bull., 21: 364-371.

Bazrafshan, E., H. Biglari and A.H. Mahvi, 2012b. Humic acid removal from aqueous environments by electrocoagulation process using iron electrodes. J. Chem., 9: 2453-2461.

Biglari, H., Y. Sohrabi, S.S. Charganeh, M. Dabirian and N. Javan, 2016a. Surveying the geographical distribution of aluminium concentration in groundwater resources of sistan and baluchistan, Iran. Res. J. Med. Sci., 10: 351-354.

Biglari, H., M. Saeidi, V. Alipour, S. Rahdar and Y. Sohrabi et al., 2016b. Prospect of disinfection byproducts in water resources of Zabol. Int. J. Pharm. Technol., 8: 17856-17865.

Biglari, H., M. Saeidi, V. Alipour, S. Rahdar and Y. Sohrabi et al., 2016c. Review on hydrochemical and health effects of it in Sistan and Baluchistan groundwater's, Iran. Int. J. Pharm. Technol., 8: 17900-17920.

Biglari, H., A. Chavoshani, N. Javan and M.A. Hossein, 2016d. Geochemical study of groundwater conditions with special emphasis on fluoride concentration, Iran. Desalin. Water Treatment, 57: 22392-22399.

Craver, V.A.O. and J.A. Smith, 2007. Sustainable colloidal-silver-impregnated ceramic filter for point-of-use water treatment. Environ. Sci. Technol., 42: 927-933.

Dunk, D., P.E. Mickey and J. Williams, 2005. Point-of-use water purification using rechargeable polymer beads. Water Wastewater Asia, 1: 40-43.

Enger, K.S., K.L. Nelson, J.B. Rose and J.N. Eisenberg, 2013. The joint effects of efficacy and compliance: A study of household water treatment effectiveness against childhood diarrhea. Water Res., 47: 1181-1190.

Fahiminia, M., M. Mosaferi, R.A. Taadi and M. Pourakbar, 2014. Evaluation of point-of-use drinking water treatment systems' performance and problems. Desalin. Water Treat., 52: 1855-1864.

Hunter, P.R., 2009. Household water treatment in developing countries: Comparing different intervention types using meta-regression. Environ. Sci. Technol., 43: 8991-8997.

Mintz, E., J. Bartram, P. Lochery and M. Wegelin, 2001. Not just a drop in the bucket: Expanding access to point-of-use water treatment systems. Am. J. Public Health, 91: 1565-1570.

Mirzabeygi, M., M. Naji, N. Yousefi, M. Shams and H. Biglari et al., 2016. Evaluation of corrosion and scaling tendency indices in water distribution system: A case study of Torbat Heydariye, Iran. Desalin. Water Treatment, 57: 25918-25926.

Mohammadi, S., E. Zamani, Z. Mohadeth, F. Mogtahedi and H. Chopan et al., 2015. Effects of different doses of simvastatin on lead-induced kidney damage in Balb-C male mice. Pharm. Sci., 20: 157-162.

Momeni, M., Z. Gharedaghi, M.M. Amin, P. Poursafa and M. Mansourian, 2014. Does water hardness have preventive effect on cardiovascular disease?. Int. J. Preventive Med., 5: 159-163.

Mousazadeh, R., 2013. Chemical and microbiological quality of drinking water in Bandar Abbas. Eur. J. Exp. Biol., 3: 254-256.

Mwabi, J.K., F.E. Adeyemo, T.O. Mahlangu, B.B. Mamba and B.M. Brouckaert et al., 2011. Household water treatment systems: A solution to the production of safe drinking water by the low-income communities of Southern Africa. Phys. Chem. Earth, 36: 1120-1128.

Peter-Varbanets, M., C. Zurbrugg, C. Swartz and W. Pronk, 2009. Decentralized systems for potable water and the potential of membrane technology. Water Res., 43: 245-265.

Ren, D. and J.A. Smith, 2013. Retention and transport of silver nanoparticles in a ceramic porous medium used for point-of-use water treatment. Environ. Sci. Technol., 47: 3825-3832.

Sajjadi, S.A., G. Asgari, H. Biglari and A. Chavoshani, 2016. Pentachlorophenol removal by persulfate and microwave processes coupled from aqueous environments. J. Eng. Appl. Sci., 11: 1058-1064.

Smieja, J.A., 2011. Household water treatments in developing countries. J. Chem. Edu., 88: 549-553.

Sobsey, M.D., C.E. Stauber, L.M. Casanova, J.M. Brown and M.A. Elliott, 2008. Point of use household drinking water filtration: A practical, effective solution for providing sustained access to safe drinking water in the developing world. Environ. Sci. Technol., 42: 4261-4267.

Souter, P.F., G.D. Cruickshank, M.Z. Tankerville, B.H. Keswick and B.D. Ellis *et al.*, 2003. Evaluation of a new water treatment for point-of-use household applications to remove microorganisms and arsenic from drinking water. J. Water Health, 1: 73-84.

Willis, R.M., R.A. Stewart, D.P. Giurco, M.R. Talebpour and A. Mousavinejad, 2013. End use water consumption in households: Impact of socio-demographic factors and efficient devices. J. Clean. Prod., 60: 107-115.