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Review Article

The Effect of Household Water Purification Devices on the Physicochemical and Microbiological Quality of Water in Iran: A Review

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Abstract
Access to clean water is one of the primary and essential needs of humans in terms of its physical, chemical, and biological properties. Every year, many people die from water-borne diseases. Household water treatment devices play a significant role on supplying water needed by different countries. This study was conducted to investigate the effect of these household water purification devices on the physical, chemical, and microbiological quality of water in different cities of Iran. This review has used different databases in Iran and Iranian studies in other international databases. Studies that did not investigate the characteristics of water were excluded, and the studies passed the quality criteria of this review as well as its data were analyzed. The studies showed that the average concentration of water parameters such as total hardness, alkalinity, dissolved oxygen, sulfate, and nitrate in the output water of these devices had decreased. Also, residual chlorine in the outlet water of all samples was lower than the standard value. To use household water purification devices, in addition to considering the benefits of using these devices, we should also pay attention to the reduction of physicochemical and microbiological quality of water.
Keywords: Water treatment, Household water treatment devices, Qualitative parameters, Microbial parameters

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Introduction

According to the World Health Organization report, more than one billion people do not have access to safe drinking water worldwide. A large number of illnesses and deaths occur annually as a result of using contaminated water. Diarrheal diseases caused by contaminated water alone causes 3 million deaths every year.[1] According to this report, household water purifiers are clear need for many parts of the world, which can reduce diseases in developing countries. Today, water desalination devices play a significant role on supplying water needed by different countries. Due to the increase in water consumption and the reduction of natural and renewable sources of fresh water, this role becomes more prominent daily.

Concerns about water-related health risks and advertising messages about home water purifiers lead to use of these devices in many areas. Previous studies showed that household water purifiers can only be helpful in an area with polluted water. At the same time, many communities use these devices as fancy tools without knowing their proper conditions.[2] The use of household water purification devices requires extensive research on the quality of their wastewater. We should select the home water purifier based on the quality of water entering into the system, the quality of the output device, and the purifier mechanism. Chlorine as a disinfectant, prevents the growth of microorganisms in the water distribution system. Still, if its remaining amount is less than the optimal amount for this purpose, it causes the growth of microorganisms in drinking water. This problem can be significant for in-home water purification systems.[3] These devices have advantages such as increased drinking water quality, though they may cause secondary pollution. PH is one of the main indicators for measuring the physical quality of water. Chemicals particles affect PH in water, which causes a decrease in water quality when it changes.

Therefore, we should measure it regularly in the water coming from these systems. The efficiency of home water purification systems in removing different pollutants is different. Higher valence ions are removed more efficiently than monovalent ions.

In these systems, most of the solutes in the water are removed, and if the device's performance is appropriate, the output water contains a lower concentration of solutes. Many of these devices remove color, hardness, turbidity, taste, and odor with surface absorption, filtration, ion exchange, and reverse osmosis.[4] Household water purification devices are the type of purification at the point of consumption. They mainly include activated carbon filters, membrane filters, ion exchangers, distillation systems, and disinfection with ultraviolet rays. These devices are divided into different types according to the purification mechanism. Ion exchange resins that convert calcium and magnesium ions soluble in water into insoluble ions absorb them and reduce the hardness of water as a result.[5]

Activated carbon filters have a high ability to remove unpleasant odors and tastes, as well as residual chlorine from drinking water. Removal of many chemicals as well as gases dissolved in water is done by carbon filters. However, carbon filters do not have a role on removing all dissolved solids in water, as well as the harmful hardness of water or heavy metals. Fiber filters (1 and 5 microns) that are made of synthetic polypropylene fibers. The strands of fibers are wrapped and compressed like a coil so that the pores in their labia are at 1 micron (i.e., 1-micron filters) or 5 microns (i.e., 5-micron filters). The function of these water filters is precisely like a strainer. So that suspended particles in city water, such as mud, sand, pipe rust, and particles caused by the decay of the piping network and other suspended pollutants that may exist in city water, are removed from the water.[6] Zeolites are natural resins that have the property of cation exchange and removal of heavy metals. One of the essential uses of zeolites is the removal of arsenic, titanium, aluminum, cobalt, chromium, aluminum, lead, zinc, etc., and cations.[7] Ceramic filters with water passage holes of about 0.5 microns prevent the passage of suspended substances and all parasites and microbes. Reverse osmosis and Nanofiltration are the most common membrane processes for preparing drinking water. So far, many water purification devices have been built and used. Six-stage devices use 6 consecutive stages to purify water as follows: Fiber filter stage is made of 100% pure polypropylene compressed 5 microns with a transparent shell to remove mud, sand, and other suspended pollution.[8] The filter's gradient structure is designed to capture larger particles towards the outer sections and smaller particles towards the inner sections. In essence, the filter's density rises progressively from the outer surface to the inner surface, allowing it to effectively trap a wide range of particle sizes: (*a*) fiber filter removes turbidity and suspended solids in water, lime, and sediments. (*b*) Granular carbon filter removes chlorine and biological pollution, and its primary function is to eliminate the unpleasant smell of water. Carbon filters remove taste, smell, color, and organic matter and free chlorine from water. The basis of work in carbon filters is absorption. (*c*) Powder carbon filter step removes the taste, color, and smell of water. Activated carbon filters absorb organic substances and some heavy metals dissolved in water and clear color, odor, chlorine, and chlorine compounds from water. (*d*) Membrane phase, a thin layer that does not allow specific ions to pass through its membrane. According to the membrane's ability to remove ions from solutions, its main application is to remove salt from aqueous solutions. (*e*) Step 5, which removes microbial water contamination. (*f*) The mineral filter stage serves the purpose of introducing essential body salts into the water. Typically, these devices incorporate a motor to enhance water pressure and a reservoir for storing the purified water. In the 5-step devices, the first five steps mentioned in 6-step devices are used. Three fiber filters, powdered active carbon, and granular active carbon (stages1-3) are used in three-stage devices. These devices do not have a pump and work by water pressure.[9] These devices consist of a ceramic filter and several different sand stages. Also, water is manually added to the upper tank of these devices. After passing through the filters, it is purified from top to bottom and enters into the lower tank.

In different regions of Iran, household water purification devices are widely used to provide high- quality water. This study was conducted to investigate the effect of these household water purification devices on the physical, chemical, and microbiological quality of water in different cities of Iran.

Water Quality Parameters

The physical parameters of water encompass the attributes that can be discerned by the senses of sight and smell (Table 1). The chemical parameters of drinking water include total dissolved solids (TDS), electrical conductivity (EC), pH, alkalinity, hardness (Table 2) and the microbiological parameters of drinking water which are given in Table 3.[10]

Materials and Methods

Search Strategy

A systematic search was performed through SID, Magiran,

Table 1. Physical Characteristics of Drinking Water

Parameters	Optimal Limit	Allowed Limit	Unit
Turbidity	1 ≥	Maximum	NTU
Color	5	Maximum	TCU
Smell	0	Maximum 2 units in 12°C Maximum 3 units in 25 °C	TON
pH	7-8.5	6.5-9	-
Taste	-	It must have general acceptance	-

Source: Iran Institute of Standards and Industrial Research - Standard 1053.

Table 2. Maximum Allowed Chemical Substances in Drinking Water

Composition	Maximum Allowable (mg/L)	Explanations
TDS	1500	In special conditions, up to 2000 mg/L is acceptable.
TS ($CaCO_3$)	500	
Cl^-	400	
SO_4	400	
NO_3	50	Standard nitrate concentration
NO_2	3	Standard nitrite concentration
NH_3	1.5	
F	0.7-1.2	Average amount of fluorine
Ca	250	
Mg	50	
Na	200	In special conditions, up to 250 mg/L is allowed.
H_2S	0.05	
Fe	0.3	
Mn	0.5	
Al	0.2	
Zn	3	
Cu	**1**	

Source: Iran Institute of Standards and Industrial Research - Standard 1053.

Table 3. The Microbiological Parameters

Microorganism	Test
Total Coliform	Maximum Possible Number (MPN)
Fecal Coliform	Membrane Filtration
Escherichia coli	Dip Test
Pseudomonas	Pseud alert Test
Heterotrophic bacteria	Heterotrophic Plate Count (HPC)
Salmonella	Cultivation in special culture environment
Nematode	Special filtration methods

Source: water standard 1011.

and CIVILICA. Also, Iranian studies in Web of Science and Science Direct databases were searched to identify articles published between 1380 and 1401 related to the subject of this study. This limitation was taken into account based on the specialized focus of the studies. The search was conducted using the following keywords within the database: "water treatment," "household water treatment devices," "physicochemical water quality," and "microbiological water quality." Furthermore, the operators "or" and "and" were utilized to both broaden and refine the search results as needed.

Definitions and Data Extraction

Initially, the titles and abstracts of the articles were assessed to ascertain whether they encompassed the subject of water treatment. Subsequently, a thorough examination of the full texts of these articles was conducted. The initial phase involved identifying articles that focused on household water purification devices. Moreover, studies that employed distinct water treatment methods were excluded from consideration. In the next step, some information such as publication year, physicochemical parameters, microbiological quality, device efficiency, and pH were systematically extracted (Table 4). The studies that did not examine water properties were excluded. Subsequently, each study that met the quality criteria were analyzed.

Results and Discussion

The results of the study are summarized in Table 4. The study by Miranzadeh and Rabbani, conducted on household water purification devices in Kashan, showed that except for fluorine, the concentration of the parameters was almost at optimal level. Concerning the pH levels, there has been a minor decrease in its concentration within the output water of the devices when compared to the pH of the incoming raw water.[11] In the study by Yari et al, the results of microbial sampling showed that 6% of the samples had microbial contamination. The findings of this research also indicated that the levels of fluoride, residual chlorine, chlorine hardness, and pH in the water obtained from these devices met the required standard values (Tables 2 and 3).[29] The results of the study by Tawanger et al in Bojnord city showed that according to the efficiency of the devices in removing parameters of hardness, alkalinity, chlorine, TDS, turbidity, fluoride, sodium, nitrate, sulfate, phosphate, and EC, determined that except for fluoride and magnesium, the parameters were almost at optimal level. The average pH concentration in the outlet water was 7.68, and residual chlorine was 0.64 mg/L. 5.41% of samples were infected with coliform bacteria, and all samples were infected with Clostridium perfringens (Tables 1-3). Fecal coliform contamination was not observed in any of the samples. Heterotrophic bacteria were also lower than the standard.[14] In another study by Ebrahimi et al, total and fecal coliform bacteria were positive in two cases in the output samples from household water purifiers. HPC exceeded the standard range of 500 cfu/mL in 67% of output samples (Table 3). The genera *Pseudomonas, Alcaligenes, Serratia*, and *Shigella* were the most abundant among gram-negative bacteria in both inlet and outlet water. However, the abundance of Proteus bacteria and gram-positive bacilli in the effluent water isolates had increased.[30] Also, the results of the study by Alipour et al in Bandar Abbas city showed that the efficiency of the devices in reducing turbidity, hardness, alkalinity, sodium, potassium, and chlorine were 45.9%, 39%, 22.3%, 30.6%, 34.9% and 53%respectively. In addition, regarding TDS and EC, it was 37.5% and 59%, respectively. The device's ability to change the water's pH was low and negative. Microbial contamination was detected in 26 out of 6 input samples, and all of these instances exhibited microbial contamination in the effluent samples.[31]

According to the Table 4, the studies conducted on household water purification devices showed that the average concentration of water parameters such as total hardness, alkalinity, dissolved oxygen, sulfate, and

Table 4. Results of Survey Water Quality Parameters

Author	Physical Parameters	Chemical Parameters (mg/L)	Microbial Parameters	Reference
Miranzadeh and Rabbani	pH: 7-8.6	Total hardness: 118 TDS1245.8 Nitrate: 46.2 Fluorine: 2 Sulfate: 24 Chlorine: 68	Not assigned	11
Yari et al	pH:<6 in all samples	- Residual chlorine in all samples is less than 1 - Chlorine less than 200 - Iron and manganese less than the maximum allowed - Alkalinity less than 50 - Low electrical conductivity of 400 micromhos/cm - The total amount of dissolved solids is less than the desired amount - Fluoride was less than 0.7 - Hardness was less than 100 - Sulfate was less than 250 - Calcium ion was less than 40	15 cases or 6% of MPN were zero (unfavorable). Out of these positive cases, 6 cases were *Escherichia coli* positive.	12
Rajaei et al	Not assigned	- Chlorine: 0.1 - Nitrite: 0.006 - Sulfate: 5 - Nitrate: 15 - Bicarbonate: 49 - Calcium :118 - Fluoride: 0	Not assigned	13
Tawangar et al	pH: 7.68 - Turbidity 0.42	-TDS: 271.24 - Chlorine residual 0.64 - Magnesium hardness: 15.56 - Calcium hardness: 3.68 - Total hardness: 124.45 - Alkalinity: 24.78 - Chlorine residual: 0.64 - Fluoride: 0.27 - Sodium: 7.87 - Chlorine: 64.35 - EC: 424.96 - Phosphate: 0.56 - Sulfate :53 - Nitrate: 2.14	- 5.41% of the samples are contaminated with coliform bacteria - All samples are contaminated with Clostridium perfringens - fecal coliform contamination was not observed in any of the samples. - Heterotrophic bacteria below the standard limit	14
Ali-Taleshi et al	pH: 7.3	It has significantly improved the quality of water used for hemodialysis for all measured elements; But in the case of continuous operation, it is possible to face a decrease in efficiency.	Not assigned	15
Nourmoradi et al	Turbidity: 61.05	- Remaining free chlorine: 100 -TDS: 70.44 - EC: 70.31 - Nitrate: 79.16 - Nitrite: 24.19 - Sulfate :48.5 - Chloride: 38.48 - Fluoride: 72.86 - Total hardness: 82.41 - Calcium hardness: 87.10 - The hardness of magnesium: 65.78 - Sodium: 95.05 - Potassium: 79.48 - Chlorine residual :100	Not assigned	16
Velayatzadeh and Payandeh		- The highest amount of metal was related to calcium (146.39 mg/L) - The lowest amount was related to cobalt (0.001 mg/L)	Not assigned	17
Ebrahimi et al	Not assigned	Not assigned	- Total and fecal coliform bacteria were positive in the output samples in two cases. - HPC was more than the standard range of 500 cfu/ml in 67% of output samples. -- *Pseudomonas*, Alcaligenes, *Serratia* and *Shigella* genera had the highest abundance among Gram-negative bacteria in both incoming and outgoing water.	18
Abolli et al	pH: higher than 5.6 in all samples	- EC: 1507 μs/cm - TDS: 786/8 - Fluoride: 0.048 - Residual free chlorine: 0.67	- Total coliform: 0.16 MPN - Fecal coliform MPN: 0.14 - Heterotrophic plate count:122 cfu/mL	19

Table 4. Continued

Author	Physical Parameters	Chemical Parameters (mg/L)	Microbial Parameters	Reference
Rezaeinia et al	pH: 5.5-6.6 Turbidity 0.09	-Nitrate 0-1.2 -Fluoride 0-0.2 -TOC 0.02-0.2	-HPC: 510-650	20
Naghizadeh et al	-	-All measured chemical characteristics were less than the national and international standards -some stations showed that the concentrations of free residual chlorine and magnesium were higher than standards	- Total coliform: 0 - Faecal coliform: 0	21
Alipour et al	Device's ability to change the PH of water was low and negative (-5.8 %)	- Hardness: 45.9 - Alkalinity: 39 - Sodium: 22.3 - Potassium: 30.06 - Chlorine: 34.9 - TDS: 37.5 - Electrical conductivity :59	In 26.6% of input samples, microbial contamination was observed	22
Jafari et al	pH: 7.21	- CO_3^{2-}: 0 - HCO_3^-: 1.03 -NO_3^-: 4.80 - Mn^{2+}: 0.1 - As^-: 0.05 -Fe^{2+}: 0.09 -Zn^+: 0.02 -EC: 427.12 -Ca^{2+}: 1.34 -Mg^{2+}: 0.93 -Na^+: 2.11 - Cl^-: 2.03 -SO_4^{2-}: 1.73	Not assigned	23
Yari et al	-pH: 7.21 - -	Not assigned	On average, for 50% of samples, the HPC level of input samples was 0-10 cfu/mL, for 42% it was 10-100 cfu/mL and for 8% it was 100-500 cfu/mL. For output samples, for 25%, the level of HPC was 0-10 cfu/mL, for 43% it was 10-100 cfu/mL, for 24% it was 100-500 cfu/mL and for 8% it exceeded 500 cfu/mL. For total coliforms, the most probable number test was positive for the first and third stages of sampling (3% input samples).	24
Malakootian et al	pH 6-7	- Chloride: 68.48 - Sulfate: 85 - Bicarbonate: 67 - Calcium: 61/21 - Magnesium: 78/97 - Sodium: 80.24 - Nitrite: 32.59 - Nitrate: 66.83 - Total hardness: 69.38	Not assigned	25
Badeenezhad et al	pH: 7.33 Turbidity: 0.65	- Total difficulty: 158 - TDS: 208.37 - EC: 353 - Sulfate :106 - Nitrate: 4.56 - Fluoride: 0.22 - Sodium: 42.5 - Chloride: 71.2	- Total coliform: 71.3 - Fecal coliform: 0	26
Masoumi et al	Not assigned	Not assigned	-P. aeruginosa was 3.70% in tap water while 20.37 % of WFS was positive - Coliform growth temperature was 37°C, and 22°C was noticed in 16.66% and 3.70% of dispensers	27
Eftekhar et al	Not assigned	Significantly decreased the fluoride concentration even as much as 100% in some cases.	Not assigned	28

nitrate in the output water of these devices had decreased compared to the input water. In many samples, the pH of the outlet water was within the standard range. Some studies have shown that there is no significant reduction in physical and chemical parameters.[32,33] The residual chlorine in the outlet water of all samples was lower than the standard value. To use household water purification devices, in addition to considering the benefits of using these devices, we should also pay attention to the reduction of residual chlorine concentration in these devices. If there is no residual chlorine in the water, there is a possibility of secondary pollution. According to the results of some studies, household water purifiers reduce heavy metals.[34,35] In the study by Ebrahimi et al, removing residual chlorine by household water purifiers led to biofilm forming on the device's filters and the storage tank by the bacteria distributed in the network. The number and diversity of bacteria in the water produced from these devices increase over time. According to studies, microbial contamination was observed in the water output from these devices.[30] In the study by Abolli et al, home water purifiers did not affect the microbial load; however, they caused changes in the values of some chemical parameters.[36] Jalali and colleagues' study observed that microbial growth was observed in the outgoing water with the disappearance of residual chlorine.[37] Qaini and colleagues' research in the fall of 1389 investigated the microbial quality of water samples from water purification devices using 64 samples. The findings showed no microbial contamination in the samples taken from water purification devices.[38] As seen in many studies, the amount of free chlorine remaining in the water from the softeners is lower than the standard value, which increases the possibility of secondary pollution in the water.[14,39] Fahiminia et al studied the quality and nutritional value of water purified by household water softeners in Qom for 6 months in 2008. In the study, 120 samples were collected and analyzed by a multi-stage method from the four regions of Qom city for chemical-physical and microbial analysis according to the standard methods. Taking into account the five key parameters for which the World Health Organization has established minimum optimal values for drinking water – calcium, magnesium, hardness, TDS, and fluoride – the examined samples did not fall within the acceptable range for drinking water in certain aspects, including pH and taste.[40] Using these devices requires extensive research on the quality of water coming out of these devices. Choosing a home water purifier should be mad based on the quality of the water entering the device, the desired quality of the output, and the device's purification mechanism. Like other natural sciences, this technology has a series of disadvantages, including high energy consumption and environmental effects.[31,41] Water treatment household devices can cause severe environmental damage by an uncontrolled discharge of outlet water (salty wastewater) because the wastewater produced in desalination devices contains residual chemicals. Throughout the process, several factors were present, including elevated levels of dissolved solids, high salinity, corrosive minerals, temperatures exceeding the ambient environment, and increased density.

The nitrite concentration of the water coming out of these devices is increasing, which is very worrying.[20,42] Many of the claims made about the performance of these devices are hype; in many cases, they have not performed quite as well, especially in the case of microbial contamination, which has very low efficiency and even increases the microbial contamination of water in some cases. Also, the device should be serviced regularly and periodically.[25] The study by Rezaeinia et al. observed that using household water purification devices causes a lack of fluoride. In the study, a significant number of bacteria was also observed.[20] The high lead concentration in the water purified by these devices was significant. They are not successful and reliable in completely removing heavy metals. In addition, due to the possible long-term health effects of soft water consumption and some microbial contamination of purified water, it is necessary to take appropriate measures for regulations affecting the quality of water produced by household water purifiers.[40] In general, using these devices is not mandatory in Iran because most of them reduce the concentration of parameters below the standard level and, in some way, reduce the taste of water and the concentration of fluoride below the average level.[34,41]

Conclusion

Due to the increasing use of household water purification devices in different cities of Iran, it is necessary to continuously monitor the quality of the water. According to the results of this research, it is recommended to periodically evaluate the quality parameters of all types of water in the desalination device to maintain the values at the optimal level and to reflect the results to the relevant authorities. In general, the use of these devices do not necessarily lead to an improvement in water quality. The use of household water purification devices requires extensive research on the quality of their output water. We should select the home water purifier based on the quality of the water entering into the system, the device's output, and the treatment mechanism.

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Conceptualization: Ali Almasi.
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Supervision: Ali Almasi.
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Visualization: Monireh Nouri.
Writing–original draft: Monireh Nouri.
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Competing Interests

The authors report no conflicts of interest.

Ethical Approval

Ethical issues have been completely considered by the authors.

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