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Research Paper

Investigation of the chemical and microbial quality of water supplied by treatment stations in Kerman city, Iran

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ABSTRACT

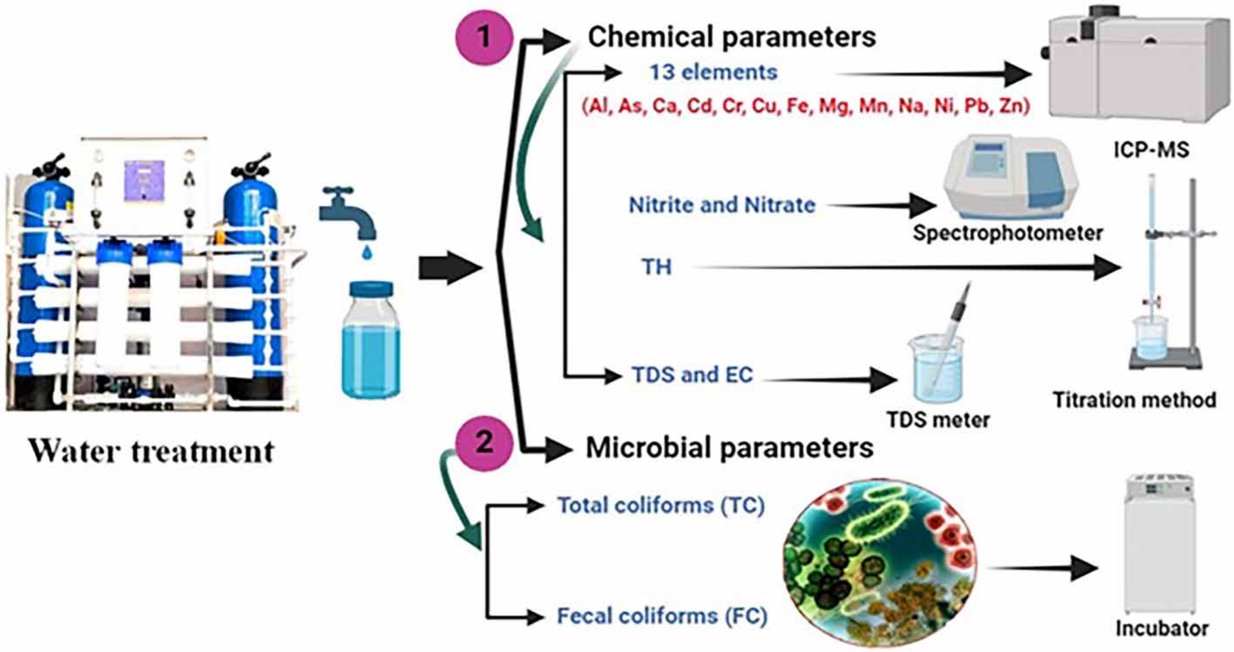
This study aimed to investigate the quality of water supplied in Kerman city, southeast Iran. Total hardness, nitrite, nitrate, total dissolved solids, electrical conductivity, total coliforms, fecal coliforms, and elements were measured in samples from five stations in four seasons in 2022. The concentration levels of (mg/L) As (0.42 ± 1.83), Cd (0.004 ± 0.01), Cu (2.51 ± 3.38), Ni (1.33 ± 0.86), and Pb (1.50 ± 2.11) were more than the standard. Total coliforms in samples (5.30 ± 7.87) were more than the national standard (0/100 mL) with a significant mean difference in seasons (p-value $= 0.04$). Fecal coliforms were detected in samples collected in autumn (2.00 ± 0.00/100 mL). The findings showed that water treatment in stations could not remove the toxic heavy metals of As, Pb, and Cd. But the microbial pollution was detected in some samples. Therefore, the use of these waters is generally not recommended. Further studies and comparisons with water quality in the distribution system can provide more useful results.

Key words: chemical quality, microbial quality, safe water, water treatment

HIGHLIGHTS

- Groundwater without any treatment process is the source of drinking water in Kerman city, the capital of Kerman province in Iran.
- This study is the first one on the water quality supplied by water treatment stations in Kerman.
- The suitability of drinking water sampled in the present study was assessed using a comparison to the national standards of drinking water.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Water is considered one of the most important elements in human life and is a critical component in the human body, comprising 65–70% of the human body. It is also an essential factor in different vital processes (Nabizadeh *et al.* 2019). Humans have the necessary, continuous, and indispensable need for water. It must meet the quality standards in terms of physical, chemical, and microbial specifications to save human health (Yousefi *et al.* 2019). In recent decades, water pollution has increased. According to World Health Organization (WHO) reports, more than 80% of diseases in the world are directly or indirectly associated with polluted water (Alarbash 2023). Polluted drinking water can cause several diseases. Some evidence shows that exposure to pesticides by consumption of polluted drinking water may cause thyroid cancer (Norouzi *et al.* 2023). Exposure to microplastics through ingestion of polluted water can cause inflammation and damage internal cell layers due to the production of reactive oxygen species (Waghmare & Dar 2024).

Various research studies have been done to measure the quality of drinking water. A study, conducted on the quality of desalinated water in commercial stores in the municipality of Janzour, Libya, showed that the majority of samples meet the Libyan chemical and bacterial standards, except for calcium (Alarbash 2023). Investigating the drinking water quality and associated health risks in the metropolis area of Pakistan showed that alkalinity, electrical conductivity (EC), and arsenic were higher than WHO standards. Also, the water quality index of most samples was poor (Sohail *et al.* 2022). Pourakbar *et al.* reported that the majority of the physicochemical parameters of the drinking water in Ardabil, Iran were below the national drinking water standards and the use of household water purification devices was not recommended in this city (Pourakbar *et al.* 2022). The evaluation of drinking water quality and health risk assessment of heavy metals in rural areas of Kurdistan, Iran showed that, except for arsenic and nitrate, the values of other parameters were below the national drinking water standard levels (Maleki & Jari 2021). Water treatment in decentralized stations is one of the methods to supply treated drinking water in Iran, especially in cities with poor-quality water in distribution systems. Groundwater sources that pass processes of chlorination and storage are the primary source of drinking water in Kerman city, the capital of Kerman province located in the southeast of Iran. To the best of our knowledge, there has been no research on the water quality supplied by treatment stations in Kerman city. Consequently, the present study aimed to fill this gap of knowledge by investigating the chemical and microbial quality of water supplied by these stations and comparing it with the WHO and national standards of drinking water.

2. MATERIALS AND METHODS

2.1. Study area and water sampling

Water sampling was done from five stations of the purified water (SPW) located in Kerman city (30° 28′ N, 57° 08′ E) (Figure 1) in four seasons in 2022. The reverse osmosis (RO) process was used to treat drinking water in these stations. The stages of the study are illustrated in Figure 2. Samples were collected according to the standard methods for the examination of water and wastewater 2017 (APHA 2017). The population of Kerman is about 738,000 people and the urban area is over 240 km^2. This region extends into a semiarid to arid climate zone and has an average temperature from −8 °C in winter to 37 °C in summer. This city is situated 1,756 meters above sea level (Naderipour *et al.* 2024). The drinking water of Kerman residences was supplied from groundwater sources that passed the chlorination and storage.

2.2. Chemical and microbial tests

The methods of Ethylenediaminetetraacetic acid (EDTA), titrimetric for total hardness (TH), colorimetric for nitrite, ultraviolet spectrophotometric screening for nitrate, the electrode for total dissolved solids (TDS), EC, the most probable number for total coliforms (TCs) and fecal coliforms, and inductively coupled plasma equipped mass spectrometry detector (ICP-MS, Model: Arcos, Germany) for 13 elements were used according to the standard methods for the examination of water and wastewater in 2017 (APHA 2017).

2.3. Statistical analysis

The value of parameters in the samples was reported by mean ± standard deviation (SD). The mean values in different seasons and five SPW were compared by the ANOVA test. Statistical analysis was done by R software version 3.6.2, and the *p*-value less than 0.05 was considered as the significant level.

3. RESULTS AND DISCUSSION

3.1. Chemical parameters

3.1.1. Elements

The values of 13 elements in the samples in four seasons have been reported and compared to the WHO and national standards in Figure 3. The order of the mean concentration of the studied elements (mg/L) followed as Na (32.17 ± 12.38) > Ca

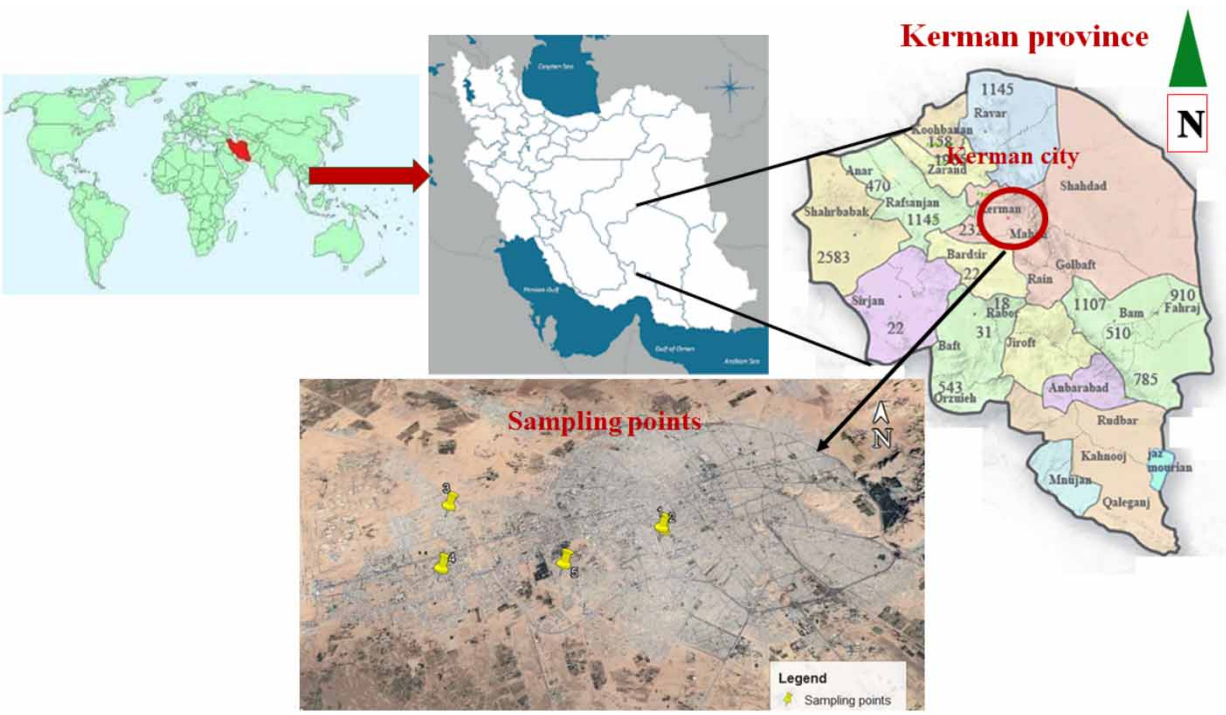


Figure 1 | Study area and water sampling points.

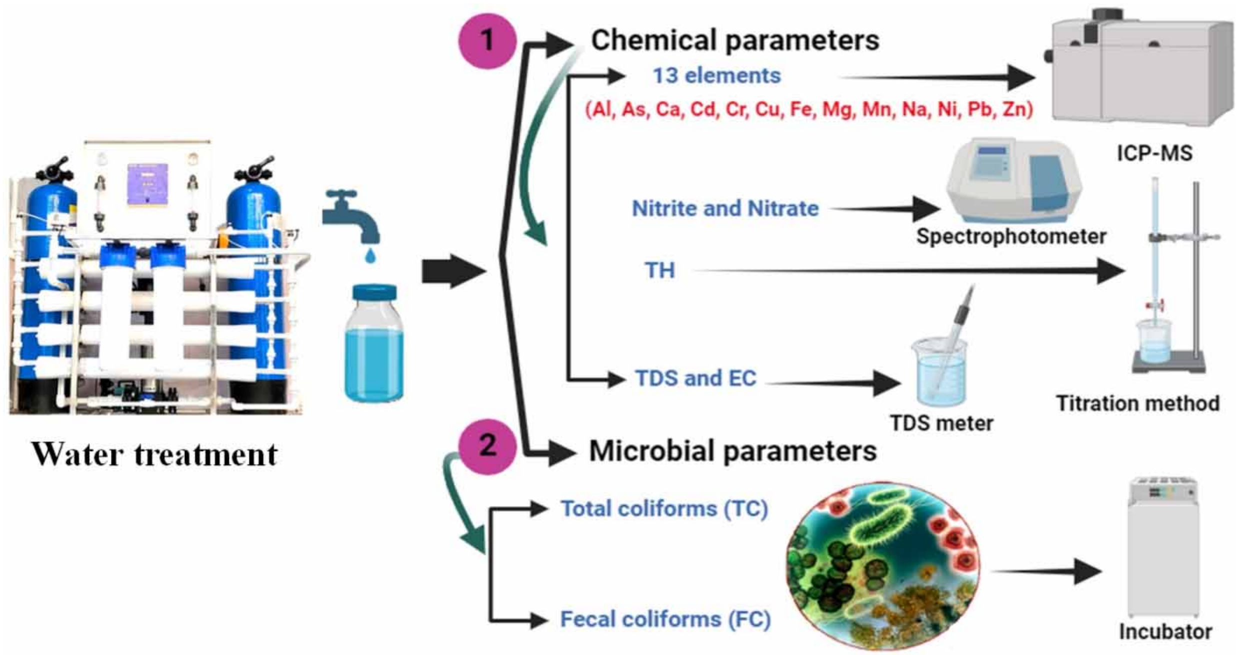


Figure 2 | Illustration of the study protocol.

(10.12 ± 5.75) > Mg (4.25 ± 2.59) > Cu (2.51 ± 3.38) > Pb (1.50 ± 2.11) > Ni (1.33 ± 0.86) > As (0.42 ± 1.83) > Mn (0.13 ± 0.34) > Fe (0.09 ± 0.25) > Zn (0.05 ± 0.06) > Al (0.02 ± 0.01) > Cr (0.01 ± 0.00) > Cd (0.004 ± 0.01). The mean concentration of Al (p-value = 0.04) and Cr (p-value = 0.01) in four seasons had a significant difference. Concentrations of Al and Cr in autumn and winter were higher than in other seasons. The mean concentration of all elements in five SPW had no significant difference. The mean values of As, Cd, Cu, Ni, and Pb were higher than those of WHO and national standards specified in Figure 3. As, Cd, Cr, Ni, and Pb are toxic heavy metals. The International Agency for Research on Cancer (IARC) defined As, Cd, and Ni as definite carcinogens to humans (group 1) and Pb as probably carcinogenic to humans (group 2A). Therefore, it is important to decrease the concentration of these elements in the purified water in stations. Among the studied elements, Fe, Mn, Al, Zn, Cu, Ca, Mg, and Na are useful. Around the world and in many countries, many researchers have published and reported the effect of low intake of useful elements on human well-being. The studies demonstrated that there is a significant protective effect of calcium intake from drinking water against colon and gastric cancer. Also, low calcium and magnesium concentrations in drinking water pose the risk of muscle atrophy (Janna *et al.* 2016). Therefore, it can be concluded that for using drinking water produced from the RO process, the water should be remineralized by passing through a filter containing minerals to increase the concentration of useful constituents and minimize the risk of some diseases associated with low concentrations of necessary elements. Indika *et al.* evaluated the performance of RO drinking water stations in Sri Lanka. The concentrations of As, Cd, and Cu in the produced water from RO stations were lower than those of WHO standards (Indika *et al.* 2021). Talaeipour *et al.* investigated desalination by nanofiltration, RO, and integrated membranes (hybrid NF/RO) employed in brackish water treatment. The results indicated that the hybrid NF/RO can remove salinity, TDS, EC, Cl^-, and Na (Talaeipour *et al.* 2017). Janna *et al.* studied demineralized drinking water in local RO stations and the potential effects on human health (Janna *et al.* 2016). In the study of Khairil *et al.*, the RO method in drinking water management is considered one of the best alternatives to overcome the clean water crisis. However, water remineralization is recommended to meet minerals with drinking water standards (Khairil *et al.* 2023).

3.1.2. Other chemical parameters

The values of other chemical parameters including TH, nitrate, nitrite, TDS, and EC in the samples in four seasons have been compared to the WHO and national standards in Figure 3. The concentrations of TH (61.85 ± 32.48, mg/L $CaCO_3$), nitrite (0.30 ± 0.32, mg/L), nitrate (1.03 ± 0.86, mg/L), TDS (126.45 ± 30.47, mg/L), and EC (194.20 ± 49.69, μs/cm) in four seasons were lower than the WHO and national standards. There are insufficient data to propose minimum or maximum

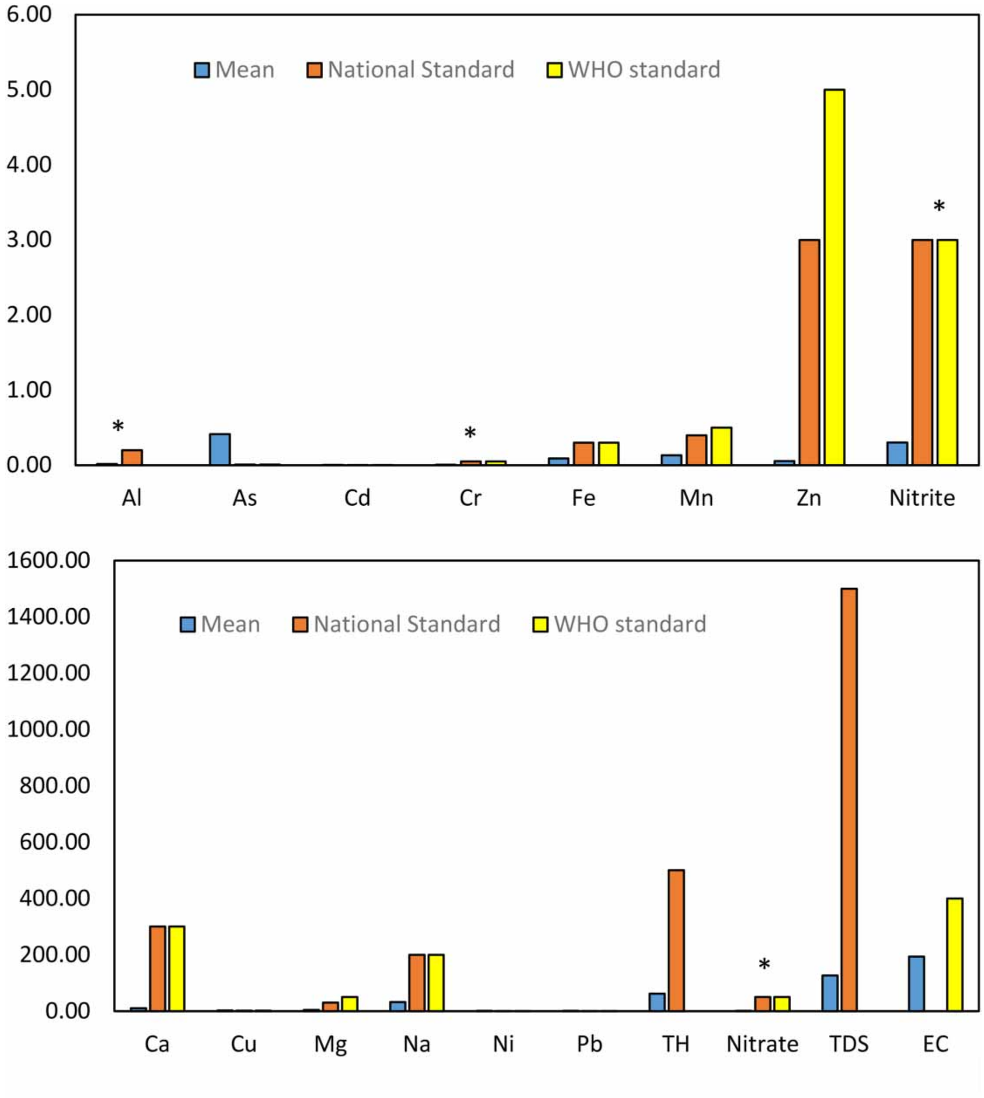


Figure 3 | Mean chemical parameters studied in the water samples ($n = 20$); elements, nitrate, nitrite, and TDS as mg/L, TH as mg/L, $CaCO_3$ and EC as μs/cm; stars show significant p-value of the mean difference between seasons. The mean concentrations of Al (p-value = 0.04), Cr (p-value = 0.01), nitrite (p-value < 0.001), and nitrate (p-value = 0.03) in four seasons had a significant difference that showed with stars (*).

concentrations of minerals. No guideline values are proposed for hardness through the WHO (WHO 2022). Public acceptability of the content of water hardness may vary considerably from one community to another. In some instances, consumers can tolerate water hardness of more than 500 mg/L $CaCO_3$. The taste threshold for the calcium ion is 100–300 mg/L, and it is probably lower than that for magnesium. The presence of hardness in the water can prevent some diseases. Yousefi *et al.* showed that the prevalence of hypertension and prehypertension was significantly higher in regions with low hardness than those with high hardness ($p < 0.001$) (Yousefi *et al.* 2019). There is some epidemiological evidence for a protective effect of magnesium or hardness on cardiovascular mortality, which is discussed and does not verify causality. As a result, no guideline values are proposed for hardness through the WHO (WHO 2022). The guideline value of the WHO for nitrate is 50 mg/L (as nitrate ion), which can protect the health of the most sensitive subpopulation, especially bottle-fed infants from methaemoglobinemia and thyroid effects (Alarbash 2023). There must be Equation (1) relating the total concentration of nitrite and nitrate and their standard values. Nitrite is more toxic than nitrate and can be formed by the microbial reduction of nitrate and *in vivo* by reduction from ingested nitrate. The guideline value of nitrite is 3 mg/L as nitrite ion. This value can protect both bottle-fed infants, who are the most sensitive subpopulation, and the general population against

Table 1 | Mean ± standard deviation (number/100 mL) of microbial characteristics studied in the water samples ($n = 20$)

Characteristic	Total coliform Number/100 mL	Fecal coliform Number/100 mL
Spring	10.80 ± 11.26	0.00 ± 0.00
Summer	6.40 ± 10.06	0.00 ± 0.00
Autumn	2.00 ± 0.00	2.00 ± 0.00
Winter	2.00 ± 0.00	0.00 ± 0.00
Mean	5.30 ± 7.87	0.50 ± 0.89
National Standard	0	0
WHO standard	0	0
P-value of the mean difference between seasons	**0.04**[a]	0.27
P-value of the mean difference between stations	0.47	0.90

[a]Bold values indicate significant *p*-value. The ranking of TCs in four seasons (Number/100 mL) followed as 10.80 ± 11.26 in the spring > 6.40 ± 10.06 in the summer > 2.00 ± 0.00 in the autumn and winter.

methaemoglobinemia. Due to the possibility of the simultaneous presence of nitrate and nitrite in drinking water, the sum of the ratios of the values of each nitrate and nitrite to its guideline value should not exceed 1 (Equation (1)) (WHO 2022). This relationship was confirmed in the present study in all four seasons and the whole year.

$$\left(\frac{\text{Concentration of } NO_3}{\text{Standard of } NO_3}\right) + \left(\frac{\text{Concentration of } NO_2}{\text{Standard of } NO_2}\right) \leq 1 \tag{1}$$

The mean concentration of chemical characteristics in four seasons had no significant difference except for nitrite (p-value < 0.001) and nitrate (p-value = 0.03). The minimum and maximum concentrations of nitrite were measured in summer and winter, respectively. The mean concentration of all chemical characteristics in five SPW had no significant difference.

3.2. Microbial parameters

In the present study, total and fecal coliforms were investigated in the water samples in four seasons, and results are shown in Table 1 as mean ± standard deviation. Total coliforms are not useful as an indicator of fecal contamination and have been proposed as a disinfection indicator (WHO 2022). Total coliforms include organisms that can survive and grow in water (Yousefi *et al.* 2018; Murei *et al.* 2024). The value of the TCs in our samples (5.30 ± 7.87) was higher than their values set in the national standard (0/100 mL). The mean difference between the seasons was significant (p-value = 0.04), but not between the stations (p-value = 0.47). Excursion of the value of TCs in the water samples in the study period could be associated with the absence of a disinfection process in the water treatment in the five SPW. The fecal coliform, *Escherichia coli*, was not detected in the samples collected from SPW, except in samples in autumn (2.00 ± 0.00). The mean difference of fecal coliform in different seasons (p-value = 0.27) and between SPW (p-value = 0.90) was insignificant. Due to the absence of disinfectant residues, the contamination of drinking water can be expected. *E. coli* occurs in high numbers in human and animal feces, sewage, and water subject to recent fecal pollution and is considered the most suitable indicator of fecal contamination. However, most strains of *E. coli* are harmless. However, specific strains, such as enterohaemorrhagic *E. coli*, can cause severe foodborne diseases (Yousefi *et al.* 2018).

4. CONCLUSIONS

In the current study, the suitability of drinking water supplied by the treatment stations in Kerman city was evaluated using water sampling in four seasons in 2022, analyzing chemical and microbial parameters and comparing them to the standards. As, Cd, Cu, Ni, and Pb were higher than the WHO and national standards. The concentration of TH, nitrite, nitrate, TDS, and EC in all seasons was not more than WHO and national standards. The TCs were detected in all samples in the values of more than the national standard. *E. coli* was detected in the samples collected in autumn.

The results of the present study showed that water treatment stations can reduce the concentration of some toxic elements, TH, nitrate, and nitrite in drinking water in the period of the study, while the concentration of some of them remained more than the standard. There is also a risk of removing useful elements. In terms of microbial factors, although fecal coliform of *E. coli* was not observed, TCs were observed due to a lack of disinfection. Therefore, according to the results, the use of these waters is generally not recommended. According to our findings, further studies on the water supplied by the treatment stations in Kerman city and other cities, continuous monitoring and supervision of the Ministry of Health on the performance of these units can be suggested.

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AUTHOR'S CONTRIBUTION

M.F. and I.A. collected and designed the study. M.F., I.A., and T.D. collected the samples. M.F., T.D., and M.N.G. analyzed the samples. I.A. statistically analyzed the data. All authors contributed to writing and reviewing the manuscript.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Alarbash, M. A. A. 2023 Evaluation of the quality of desalinated water in commercial stores and its suitability for drinking from a chemical and bacterial point of view in the municipality of Janzour. *International Journal For Multidisciplinary Research* **5**, 12.

APHA. 2017 *Standard Methods for Examination of Water and Wastewater*. American Public Health Association, Washington, DC.

Indika, S., Wei, Y., Hu, D., Ketharani, J., Ritigala, T., Cooray, T., Hansima, M., Makehelwala, M., Jinadasa, K. & Weragoda, S. K. 2021 Evaluation of performance of existing ro drinking water stations in the north central province, Sri Lanka. *Membranes* **11**, 383.

Janna, H., Abbas, M. D. & Mojid, M. H. 2016 Demineralized drinking water in local reverse osmosis water treatment stations and the potential effect on human health. *Journal of Geoscience and Environment Protection* **4**, 104.

Khairil, D. F., Insani, M., Setiawan, A., Febryanti, F., Rabbi, E. F., Barlian, E., Dewata, I., Syah, N., Heldi, H. & Umar, I. 2023 Reverse osmosis (RO) drinking water management as the best solution to overcome the clean water crisis in Pinang Island. *Science and Environmental Journal for Postgraduate* **6**, 254–258.

Maleki, A. & Jari, H. 2021 Evaluation of drinking water quality and non-carcinogenic and carcinogenic risk assessment of heavy metals in rural areas of Kurdistan, Iran. *Environmental Technology & Innovation* **23**, 101668.

Murei, A., Kamika, I. & Momba, M. N. B. 2024 Selection of a diagnostic tool for microbial water quality monitoring and management of faecal contamination of water sources in rural communities. *Science of the Total Environment* **906**, 167484.

Nabizadeh, R., Hadei, M., Zarei, A., Baghal Asghari, F. & Mohammadi, A. A. 2019 Northwest of Iran as an endemic area in terms of fluoride contamination: A case study on the correlation of fluoride concentration with physicochemical characteristics of groundwater sources in Showt. *Desalination and Water Treatment* **155**, 183–189.

Naderipour, M., Hashemi, M., Mirzaei, M., Haghdoost, A. A. & Faraji, M. 2024 Association of social, demographic, ecological factors, and underlying diseases with COVID-19 mortality rate: A crosssectional study. *Environmental Health Engineering And Management Journal* **11**, 15–24.

Norouzi, F., Alizadeh, I. & Faraji, M. 2023 Human exposure to pesticides and thyroid cancer: A worldwide systematic review of the literatures. *Thyroid Research* **16**, 13.

Pourakbar, Z., Dargahi, A., Mokhtari, A., Vosoughi, M. & Sadeghi, H. 2022 Investigating water quality parameters of the water of the distribution network, the outlet water of the household water purification device, and the widely consumed bottled waters distributed in the city of Ardabil, and comparing them with drinking water standards in 2019. *Archives of Hygiene Sciences* **11**, 248–257.

Sohail, M. T., Ehsan, M., Riaz, S., Elkaeed, E. B., Awwad, N. S. & Ibrahium, H. A. 2022 Investigating the drinking water quality and associated health risks in metropolis area of Pakistan. *Frontiers in Materials* **9**, 864254.

Talaeipour, M., Nouri, J., Hassani, A. & Mahvi, A. 2017 An investigation of desalination by nanofiltration, reverse osmosis and integrated (hybrid NF/RO) membranes employed in brackish water treatment. *Journal of Environmental Health Science and Engineering* **15**, 1–9.

Waghmare, P. R. & Dar, M. A. 2024 Report of Microplastic Presence in Drinking Water. InMicroplastic Pollution. Singapore: Springer Nature Singapore.

WHO. 2022 *Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First and Second Addenda*. Geneva, World Health Organization.

Yousefi, M., Najafi saleh, H., Yaseri, M., Mahvi, A. H., Soleimani, H., Saeedi, Z., Zohdi, S. & Mohammadi, A. A. 2018 Data on microbiological quality assessment of rural drinking water supplies in Poldasht county. *Data in Brief* **17**, 763–769. Geneva World Health Organization.

Yousefi, M., Najafi saleh, H., Yaseri, M., Jalilzadeh, M. & Mohammadi, A. A. 2019 Association of consumption of excess hard water, body mass index and waist circumference with risk of hypertension in individuals living in hard and soft water areas. *Environmental Geochemistry and Health* **41**, 1213–1221.

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