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# Survey of Fluoride, Chlorine, Potassium, Sodium, and Trihalomethane contents in the drinking water of five major universities in Iran

**Amir Salari**✉**, Saeid Khanzadi, Zeynab Rezaei**

Department of Food Hygiene and Aquaculture, Faculty of Veterinary Medicine, Ferdowsi University of Mashhad, Mashhad, Iran

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## ABSTRACT

Water quality directly influences individual and public health. Monitoring of water supplies and their sanitation is of paramount importance. The present study aimed to determine the concentrations of fluoride, chlorine, potassium, sodium, and trihalomethanes in the drinking water of five major universities in Iran. This descriptive study was conducted during January 2016-2017. In total, 60 samples of drinking water were collected from the central kitchens of the universities, including Ferdowsi University of Mashhad (two places), Gilan University, Kerman University, Hamedan University, and Shiraz University. Water samples with polyethylene terephthalate (PET) containers were obtained from the sources and shipped to the water laboratory in standard conditions. Parameters such as fluoride, chlorine, potassium, sodium ions, and trihalomethanes were measured in accordance with the national standard methods. According to the results, fluoride levels were within normal limits in all the samples, while chlorine and potassium ions were below the standard level. Similarly, sodium ion and trihalomethanes were below the standard limit in all the samples. Although the concentrations of the studied parameters were not above the standard limit, the periodic monitoring of water chemical quality is crucial to controlling community health.

**Keywords:** Drinking Water, Water Chemical Quality, University

## Introduction

Water quality is an important health issue that influences individual and public health. Periodic monitoring of water to control its sanitation is of paramount importance. The World Health Organization (WHO) is one of the indicators of health development in developing countries through supplying healthy water systems. Fluorine is an essential element in the formation of bones and teeth. Fluorine is found in negligible amounts in dietary intakes, and drinking water is its main route of absorption. The WHO recommends the appropriate amount of 0.05 up to 1 mg/l for additive fluoride.[1,2,3,4,5]

Epidemiological evidence suggests that fluorine within the standard limit could reduce tooth decay, while its high concentrations (1.7 mg/l) may lead to fluorosis (yellow and brown spots on the teeth at the concentrations of higher than 3-6 mg/l) and skeletal fluorosis. On the other hand, excessive absorption of fluorine through food and drinking water leads to chronic complications, such as low hemoglobin levels, gastrointestinal disorders, loss of teeth at young ages, increased risk of pelvic fractures in the elderly, immune system problems, and learning disorders. Fluoride contact depends on the temperature of drinking water. At high temperatures, the fluoride content in water should be less than 1.5 mg/l.[4,5,6]

A study focusing on the amount of fluoride in the drinking water in Behshahr (Iran) revealed that fluoride concentrations were within the range of 0.12-0.39 mg/l. Examination of drinking water in some areas of Bushehr has also indicated that fluoride concentrations were lower than the national and WHO standards. The findings of another study in Mianeh (Iran) showed that the mean fluoride concentration was lower than 0.7 mg/l in drinking water, which is below the optimal national and WHO standards.[7]

✉ *Amir Salari*
*a-salari@um.ac.ir*

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Sodium ions were another important parameter in the present study. The risk of heart diseases has been reported to increase at high sodium levels, which could lead to mortality in children. A high-sodium diet has been associated with hypertension and the narrowing of the walls of small arteries, which in turn causes damage to the brain and eyes. Potassium is one of the anions in drinking water, and its concentration in water is considered to be an indicator of water pollution by chemical fertilizers.[8,9]

Chlorine is another important element in drinking water. Due to its low cost and high efficiency, chlorine has a wide range of applications in water treatment. Therefore, the unprincipled release of urban and industrial wastewater contributes to the increase of this pollutant in groundwater resources. According to the WHO standards, the optimal amount of chlorine is 250 mg/l, which rises up to 400 mg/l in the permitted state. The remaining chlorine could combine with organic substances in water and form certain compounds, such as trihalomethanes. Additionally, this anion may cause abortion, eye diseases, and nervous disorders.[10,11]

One of the main challenges in utilizing surface water sources is the high concentrations of natural organic materials leading to the formation of trihalomethanes, which is in turn associated with carcinogenic risks and destructive effects on the respiratory system of humans and animals.[12]

Trihalomethanes (THMs) are halogen-substituted, single-carbon compounds with the general formula of $CHX_3$, where X represents a halogen that may be fluorine, chlorine, bromine, iodine or combinations of these elements. The THMs that are most commonly present in drinking water are chloroform ($CHCl_3$), bromodichloromethane or dichlorobromomethane ($CHBr_2Cl$) (BDCM), dibromochloromethane or chloro-dibromomethane ($CHClBr_2$) (DBCM), and bromoform ($CHBr_3$). Data on the derivation of drinking water guidelines are limited to these compounds.[13]

THMs are formed in drinking water primarily as a result of the chlorination of the organic materials present in intact water supplies. The rate of THM formation increases as a function of the chlorine and humic acid concentration, temperature, pH, and bromide ion concentration. In addition to common THMs, chloroform is also the principal disinfection by-product in chlorinated drinking water. In the presence of bromides, brominated THMs are formed preferentially, with the chloroform concentrations decreasing proportionally.[14,15]

Several studies have determined the concentration of THMs in drinking water sources. For instance, Noshasadi *et al*. claimed that the mean chloroform concentration in the drinking water network of Shiraz (Iran) was 39 µg/l, which is below the standard limit. Moreover, Jafari *et al*. have concluded that the concentrations of these compounds at the output of the chlorination unit (the beginning of the drinking water distribution network of the city) were higher than the guidelines of the United States Environmental Protection Agency (EPA) based on examining the amounts of THMs in the drinking water sources in Lahijan (Iran). In this regard, the findings of Babaei *et al.* have indicated that the concentrations of THMs were above the EPA and WHO limits in some of the obtained samples from the drinking water distribution network in Ahvaz (Iran). In another research, Mohammadian Fazli *et al.* measured the mean concentrations of THMs in the drinking water network of Zanjan (Iran) during 2012-2013, which were reported to be lower than the national and international standards.[14,16]

Given the importance of the health and quality of drinking water, measuring the levels of the mentioned compounds and their monitoring in drinking water are essential.

## Materials and Methods

This descriptive study was conducted during January 2016-2017. In total, 60 drinking water samples were collected from the distribution network (central kitchens) of five Iranian universities, including Ferdowsi

University of Mashhad (two places), Gilan University, Kerman University, Hamedan University, and Shiraz University. The water of the distribution networks in these cities originates from underground resources. Water samples with polyethylene terephthalate (PET) containers were obtained from the sources and shipped to the water laboratory in standard conditions. Sample size was estimated based on 5% error degree, 95% accuracy, and possibility of sample loss to 15.

After shaking the sample containers, one milliliter of water was mixed with 0.1 milliliter of total ionic strength adjustment buffer III (TISAB II, Orion, MA, USA). Fluoride concentrations of all the samples were determined using fluoride ion selective electrode (model: 96-09, ATI Orion) in conjunction with an ISE meter (model: 720A, ATI Orion). The fluoride standards within the range of 0.001-10.00 mg/l were used to calibrate the measurements.[17]

In the present study, chlorine concentrations were measured using the Mohr method (argentometric method). Moreover, the photometer flame method was used to determine the levels of potassium and sodium in the samples. Gas chromatography was also employed to verify the concentrations of THMs after preparing the samples in accordance with standard methods.[16,18]

According to the EPA, a sterilized 100-millimeter glass container that is washed by detergent and distilled water could be used to separate contaminants, followed by washing with deionized water and placing on dry heat (Four) at the temperature of 250 ºC for 30 minutes in order sterilization and releasing the volatile compounds. Additionally, sodium thiosulfate was added to the sampling glasses in order to prevent the formation of more THMs during the transportation and storage of the samples in the laboratory. Duration of sampling and analysis was less than six hours. Following that, the concentration of THMs with the chloroform index was measured using a mass spectrophotometer. In accordance with the guidelines of the Institute of Standards and Industrial Research of Iran (ISIRI) and EPA, a standard curve was used to construct chloroform concentration (300 μg/l). Afterwards, the extraction of the upper atmosphere was used to extort the compounds after equilibrium between the gas and liquid phases, and a specific amount was injected. Volatile organic materials in the samples reacted with the detector and were identified and measured.[19,20] In the following, a map of the area studied is shown in Fig. 1.

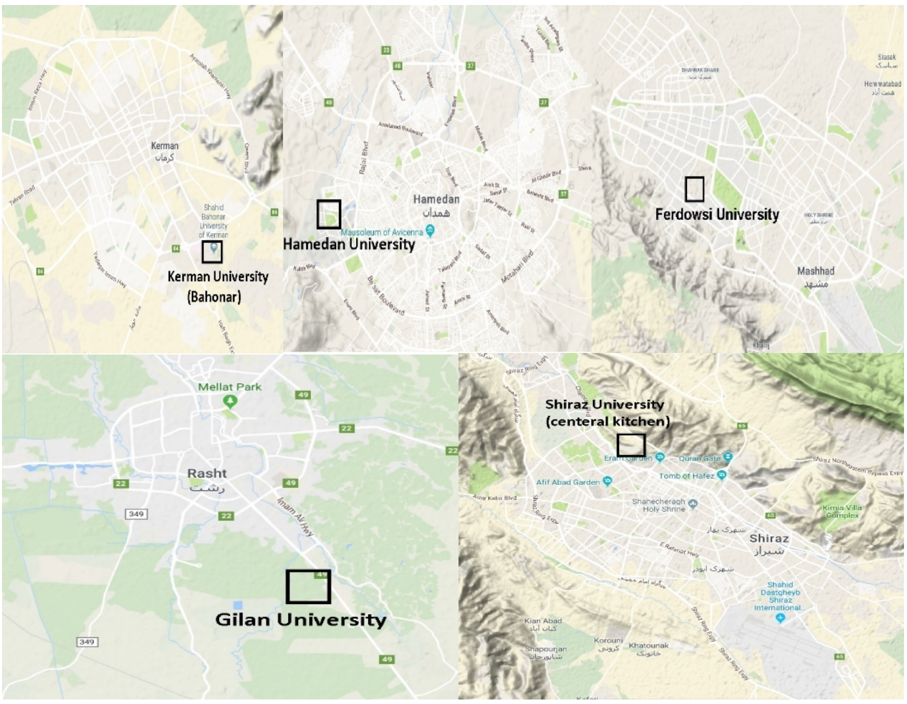

Fig. 1. Map of source sampling location

## Results and Discussion

Measurement of the THMs and other chemical parameters and their comparison with the national and international guidelines are presented in Table 1 and Figures 2-9.

Table 1. Value of chemical parameters of drinking water of universities and its comparison with national and global standard

| Parameters | National standard | WHO standard | Ferdowsi P.1 | Ferdowsi P.2 | Shiraz | Kerman | Gilan | Hamedan |
|---|---|---|---|---|---|---|---|---|
| Chlorine (mg/L) | 400 | 250 | 49.6 | 95.5 | 92.17 | 111.7 | 65.6 | 56.72 |
| Fluoride (mg/L) | 1.5 | 1.5 | 0.5 | 0.3 | 0.47 | 0.7 | 1.04 | 0.6 |
| Sodium (mg/L) | 200 | 200 | 65.7 | 113.1 | 64.22 | 67.5 | 55.8 | 17.1 |
| Potassium (mg/L) | 12 | - | 3.4 | 5.86 | 2.3 | 2.91 | 1.96 | 1.76 |
| Chloroform (µg/L) | 300 | 300 | 1.08 | 0 | 1.08 | 2.29 | 1.08 | 8.16 |
| Dichlorobromomethane (µg/L) | 60 | 60 | 6.92 | 0 | 1.23 | 1.23 | 1.23 | 2.58 |
| Dibromochloromethane (µg/L) | 100 | 100 | 10.12 | 5.2 | 8.91 | 1.84 | 1.84 | 1.84 |
| Bromoform (µg/L) | 100 | 100 | 2.94 | 0 | 2.94 | 2.94 | 2.94 | 2.94 |

According to the information in Table 1, the concentrations of the studied parameters in the all the drinking water samples from the universities were below the recommended limits. Since groundwater is largely affected by the type of the ground texture that passes through, it contains various minerals. In the case of fluoride, if the ground texture that the water passes through is composed of feldspathic rocks, the water contains substantial fluoride. Otherwise, most groundwater has low levels of fluoride, which is required to prevent flushing and dental caries. Fluoridated water is generally a safe, accessible option to prevent dental caries in all populations.[21,22]

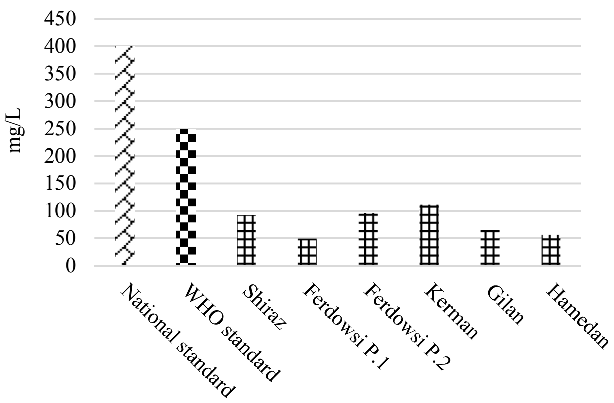


Fig. 2. Comparison of the amount of chlorine to the national and global standard

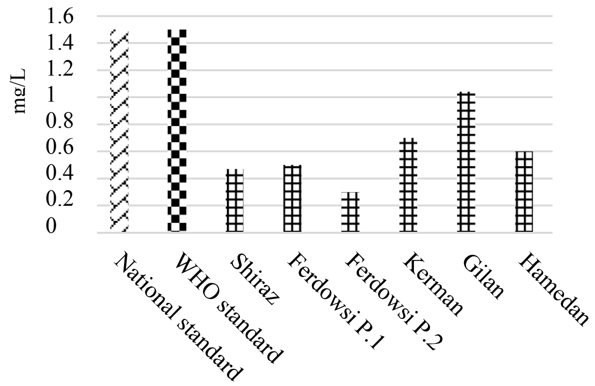


Fig. 3. Comparison of the amount of fluoride to the national and global standard

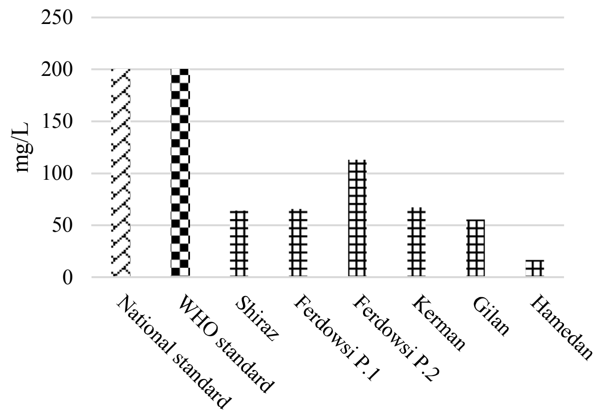


Fig. 4. Comparison of the amount of sodium to the national and global standard

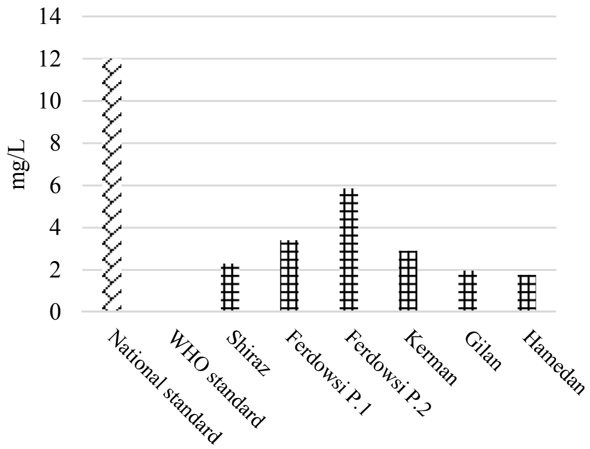


Fig. 5. Comparison of the amount of potassium to the national and global standard

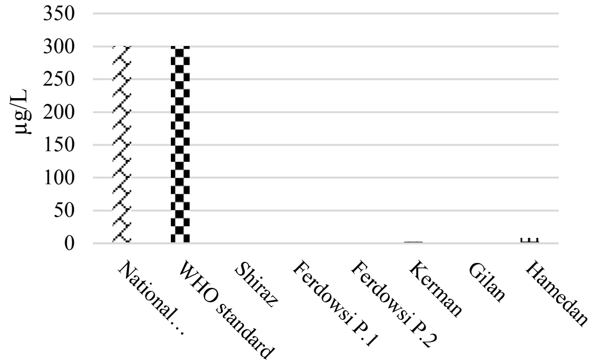


Fig. 6. Comparison of the amount of chloroform to the national and global standard

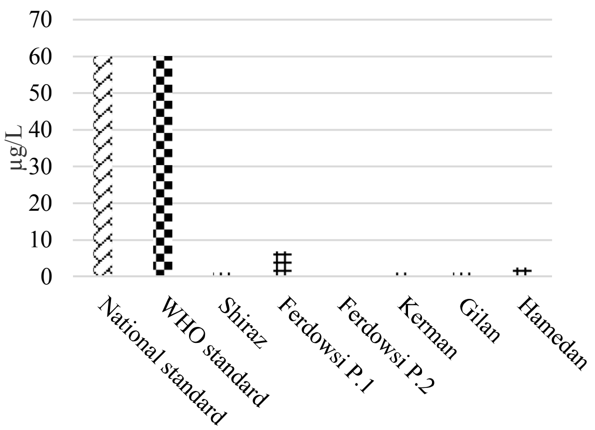


Fig. 7. Comparison of the amount of dichlorobromomethane to the national and global standard

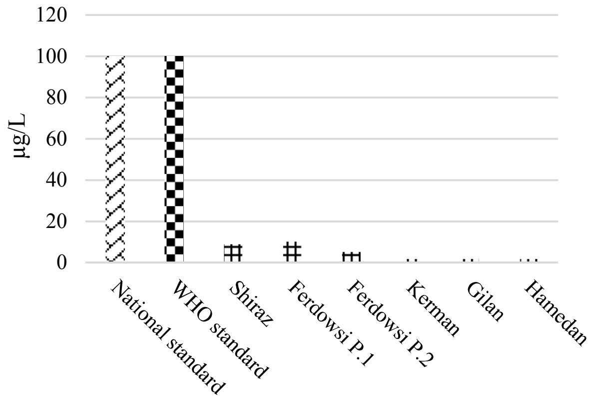


Fig. 8. Comparison of the amount of dibromochloromethane to the national and global standard

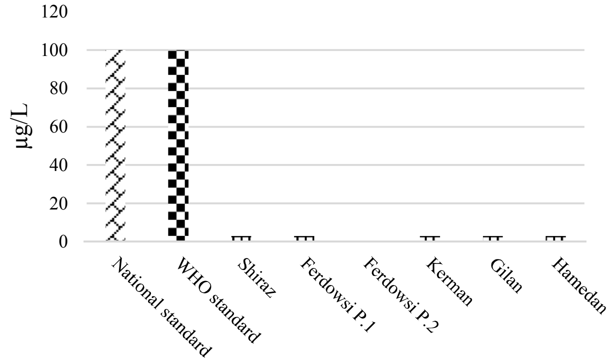


Fig. 9. Comparison of the amount of bromoform to the national and global standard

In the present study, the lowest concentration of fluoride was observed in the drinking water samples from Ferdowsi University of Mashhad (place two) (0.3 mg/l), which is less than the minimum level needed for dental health. By contrast, the highest level of fluoride was detected in the drinking water samples from the University of Gilan (1.4 mg/l), which is below the national and global guidelines (1.7 mg/l). In some regions in Iran, additional fluoride levels have been reported. In general, the northern and central provinces of Iran have the lowest fluoride concentrations, whereas the highest rates are reported in the southern provinces in water resources. Additionally, in the most regions in Iran, fluoride deficiency has been reported to be the cause of dental caries in numerous patient referrals.[23]

In recent years, several studies have been focused on the amount of fluoride in drinking water. In a study in Iran, the level of fluoride in the drinking water in Tabas was estimated 0.71 and 0.58 mg/l in summer and winter, respectively.[24] Furthermore, the findings of Ramezani *et al*. indicated that the mean fluoride concentration was 0.35±0.22 mg/l in Kerman province (Iran). However, the amount of fluoride was higher in our study compared to the aforementioned studies.

According to the literature, Zarand and Rafsanjan provinces have the highest and lowest fluoride concentrations in Iran, respectively. In Khorasan province, the mean fluoride concentration has been reported to be 0.33±0.49 mg/l. Our findings were within the same range as these areas.[25] The results of a study regarding the amount of fluoride in the drinking water in Behshahr (Iran) have revealed that fluoride concentrations were within the range of 0.12-0.39 mg/l. Moreover, examination of the drinking water in some areas of Bushehr (Iran) has demonstrated that fluoride concentrations were lower than the national and WHO standards. On the other hand, another study in Mianeh (Iran) indicated the mean fluoride concentration to be even lower than 0.7 mg/l in drinking water, which is below the optimal national and WHO standards.[7]

In the present study, the lowest amount of chlorine in the drinking water was observed in Ferdowsi University of Mashhad (place one), while the highest concentration was reported in Kerman University. However, the highest amount of this compound was less than the global and national guidelines (250 and 400 mg/l, respectively). In a study by Heydari *et al*., the results showed that the chloride content was higher than the permissible limit (200-600 mg/l) in only 2% of the samples and lower in only 5% of the samples, whereas 93% of the samples were within the optimum limit in this regard.[18] High concentrations of chloride may cause an increase in the salt level of drinking water, which increases the rate of corrosion in water pipes. Additionally, chloride concentrations of higher than 600 mg/l could markedly impair water portability. In the study by Pourfallah *et al*., the concentrations of chloride in three samples were higher than the prescriptive limits.[26,27]

In the present study, the levels of sodium and potassium ions in all the samples of drinking water obtained from the universities were lower than the recommended limits. In a similar study by Heydari *et al*., the minimum (99 mg/l) and maximum sodium contents ($Na^+$) (446 mg/l) were reported in the samples collected from Kashan West-2 and Kashan East-2 regions, respectively. In the mentioned research, the potassium ($K^+$) content of the water samples was within the range of 6.75-13.71 mg/l, and the minimum (6.75 mg/l) and maximum $K^+$ contents (13.71 mg/l) were observed in the samples obtained from Aran and Bidgol-South 2 and Aran and Bidgol-West 4 regions, respectively. Sodium and potassium affect the desirability, odor, and taste of water. In this regard, the results of a study by Pourfallah *et al*. indicated that $Na^+$ and $K^+$ contents were below the permissible limits.[18,27]

Measurement of THMs was the primary objective of the present study. The THM content in the samples was below the national and international standards. In this respect, the results obtained by Mohammadi *et al*. showed that THM concentration was less than the EPA and WHO guideline values. It is notable that in the mentioned research, all the samples were collected from Isfahan city (Iran). Evidently, the distance from the treatment plant was important parameter in the THM production in the water distribution network. By increasing distance, THM concentrations were observed to rise. According to the study by Kiani *et al*. indicated that the concentration of THMs in the drinking water in Abbas Abad water treatment was lower than the permissible limits which is consistent with the results of the present study.[14,16]

In another research by Nowsadi *et al*., which was conducted in Shiraz drinking water network (Iran), the maximum mean concentration of THMs was associated with the stations with high organic matter loading. By examining the amounts of THMs in the drinking water sources in Lahijan (Iran), Jafari *et al*. concluded that the concentration of these compounds was higher than the EPA guidelines at the output of the chlorination unit and the beginning of the drinking water distribution network of the city.[14]

## Conclusion

The main objective of the present study was the chemical analysis of drinking water in five major universities in Iran. Although all the studied parameters were below the recommended guideline values, the only issue was the level of fluoride, which was lower than these limits despite performing the enforcement of fluoridation in these locations. According to the results, the mean concentration of THMs in the samples was less than the recommended daily allowance. On the other hand, the mean chloroform concentration as a main compound among THMs was lower than the EPA guidelines. Therefore, it could be concluded that the consumption of drinking water with THMs leads to health hazards for the consumers in the studied areas. Nevertheless, the control and constant monitoring of the composition of drinking water are strongly recommended in order to assure consumer health. The results of the study indicated that the mean density of most of the chemical parameters in the drinking water samples was lower than or within the WHO standard limits. The only issue in this regard would be the level of fluoride, which was below the recommended range although the enforcement of fluoridation in underway in these locations.

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