University of Aden Journal of Natural and Applied Sciences., vol.29(2) (2025) 47-54

University of Aden Journal of Natural and Applied Sciences

Journal homepage: https://uajnas.adenuniv.com

Research Article

Assessment of Fluoride Content in the Drinking Water of Al-Musaymir District, Lahij Governorate, Yemen

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https://doi.org/10.47372/uajnas.n2.a05

ARTICLE INFO

Received: 5/11/ 2025

Accepted: 28/3/ 2026

Keywords:

Fluoride, Spectrophotometer, Drinking Water Quality, Al-Musaymir District

Abstract

The problem of the study was that there is deterioration in the characteristics of drinking water in Al-Musaymir district, Lahij Governorate, also, appearance of dental fluorosis and osteoporosis in Children. The present study aimed to investigate the concentration of fluoride and some physical properties of drinking water in the study area and to compare it with standards of the World Health Organization (WHO). Seventeen of drinking water samples were collected from surface water. Temperature and pH were measured directly in situ using a graduated thermometer and pH meter (HQ40D multi/HACH), while turbidity and fluoride content were analyzed in the laboratory. Samples were taken from the wells that were examined in coordination with Aden Water Supply Local and Sanitation Corporation (AWSLC). A HACH Spectrophotometer (DR 900 model) and a HACH UV-Spectrophotometer (DR 5000 model) were used for measuring of turbidity and Fluoride (F^-), respectively. The results showed that the concentration of fluoride in most of the studied samples exceeded the permissible limit for WHO. The study recommended the government institutions and organizations to conduct a study of the soil and rocks, in addition to knowing the reasons for increasing fluoride concentration in water and then finding solutions.

1. Introduction

Fluorides are naturally occurring mineral substances found in water. When present at optimal levels in drinking water, fluoride provides benefits to both humans and the environment; however, excessive amounts can lead to adverse health effects, such as damage to tooth enamel resulting in dental fluorosis. Prolonged exposure to high fluoride levels may also cause various bone diseases. Fluoridation involves the controlled addition of fluoride compounds to drinking water to adjust concentrations to levels between 0.8 and 1.0 mg/L, which is beneficial for preventing tooth decay. The concentration of fluoride in groundwater varies depending on the water table's depth, the amount of rainfall, and the geological composition of the soil in the area [**24**]. While low levels of fluoride have positive health impacts, high concentrations pose a significant threat to human health [**33**]. Specifically, low fluoride concentrations are beneficial in preventing dental caries, whereas higher concentrations increase the risk of dental fluorosis, and levels exceeding 1.5 mg/L can lead to skeletal fluorosis [**5**, **22, 25, 27**]. Excessive fluoride in drinking water has become a major public health concern, with several regions in Yemen reporting levels that exceed the World Health Organization (WHO) permissible limit of 1.5 mg/L [**14**,**22**,**23**]. Fluorosis remains an endemic problem in Yemen, with more affected areas being regularly identified across different parts of the country. Children up to 12 years of age are the most susceptible to fluorosis because their body tissues are in the formative and growth stages during this period. A recent report from the General Authority of Rural Water Projects (GARWP) indicates a marked increase in fluoride content in groundwater (between 2000 and 2006) in districts within several governorates, including Sana'a, Ibb, Dhamar, Taiz, Al-Dhalei, and Raimah. The highest fluoride concentrations in drinking water have been reported in certain districts of the Sana'a governorate, particularly Sanhan [**29**].

The presence of fluoride in groundwater is primarily due to natural geological formations in regions such as the Al-Musaymir district and the hot springs of Shara'a and Kirsh in the Lahj Governorate [**26**], as well as in other Yemeni

governorates [**22**,**23**] including Al-Dhalea [**5**,**7**,**27**], Aden and Lahij [**21**], Hadhramaut [**10**], Taiz [**4**,**9**,**18**], Dhamar [**2**], and Sana'a [**3**,**5**,**29**]. Due to the deteriorating quality of drinking water in the Al-Musaymir district—affecting both improved and unimproved sources—and its impact on the local population, this study addresses the problem by assessing the suitability of the water for consumption through the investigation and analysis of drinking water samples. This research utilizes an experimental methodology to analyze and solve the study problem. The main objective of this paper is to investigate fluoride concentrations in drinking water within the study area, compare them with WHO standards, and evaluate their suitability for human consumption. Water intended for human consumption must be free from pathogenic organisms and chemical concentrations that could pose a hazard to health [**31**]. Access to high-quality drinking water is essential for the general well-being of all people [**16**,**20**]. While low concentrations of fluoride in drinking water have beneficial effects on dental health [**17**, **25**], excessive exposure can lead to numerous adverse health impacts [**25**]. These include diseases such as dental mottling, bone diseases, and lesions affecting the endocrine glands, thyroid, kidneys, liver, and other vital organs [**15, 28**].

In several regions of the Al-Musaymir district, health problems such as osteoporosis, rickets, bone curvatures, dental fluorosis, and dental caries (especially in children) have been observed, which may result from high fluoride concentrations that promote the excretion of calcium from the body. The primary objective of this study is to investigate fluoride concentrations in the drinking water within the study area, compare these levels with the World Health Organization (WHO) standards, and assess its suitability for human consumption. Furthermore, the research aims to determine certain physical properties of the water and provide the local community with sufficient knowledge regarding the issue, while suggesting potential solutions for future prevention. This study employs an experimental methodology to analyze and address the identified problem by evaluating water samples from both improved and unimproved sources.

Study area:

The study area is located in the western part of Lahij Governorate, with a population of about 38310, an area of more than 533 Km^2 approximately, and about 55 kilometers away from the Governorate capital, bordered by Mawiyah district in Taiz to the west, Al-Azariq district in Al-Dhalia to the north-east, Al-Qubeita and Tuban districts to the south, and Al-Mallah district to the east. Also located in: Latitude: 13°.43, 85’ N & Longitude: 44°. 611, 03" E (Figure 1 and Table 1).

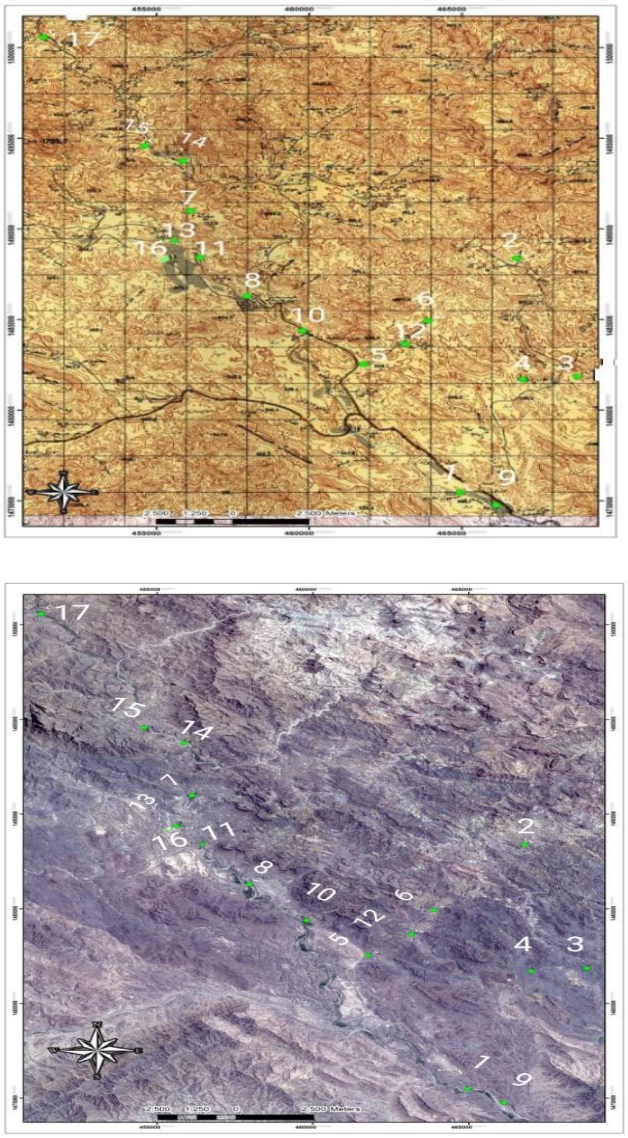

Figure (1): Showing the surface wells Map for samples locations at Al-Musaymir district in Lahij governorate

2. Materials and methods:

The surface water samples were analyzed for quality in accordance with the American Public Health Association (APHA) standards. Physical parameters, including temperature and pH, were measured directly in situ using a graduated thermometer and a digital pH meter (HQ40D multi/HACH). Conversely, turbidity and fluoride content were analyzed under laboratory conditions. The sampling and examination process were conducted in coordination with the Aden Water Supply Local and Sanitation Corporation (AWSLC). For analytical measurements, a HACH Spectrophotometer (DR 900 model) was utilized to determine turbidity, while a HACH UV-Spectrophotometer (DR 5000 model) was employed for measuring fluoride concentrations.

Table 1: Location Details with latitude and longitude of surface wells samples collected from Al-Musaymir district in Lahij governorate.

NO.	Name sample	Name of well	Village	Depth (m)	Latitude	Longitude
1	Sample-1	Fadhal Saeed	Al-Sarhan'a	11	13°20'47"N	44°40'35"E
2	Sample-2	Fara'a	Fara'a	16	13°27'47.25"N	44°41'35.75"E
3	Sample-3	Nakhela'a	Nakhela'a	14	13°24'9.99"N	44°41'43"E
4	Sample-4	Mutein	Nakhela'a	16	13°24'15"N	44°42'42"E
5	Sample-5	Qayif	Qaaf	10	13°24'37"N	44°38'49" E
6	Sample-6	Qaaf	Qaaf	13	13°25'55"N	44°39'59" E
7	Sample-7	Bashria	Bashria	12	13°29'11.6"N	44°35'40.7"E
8	Sample-8	Alhaqaf	Al-Musaymir Center	20	13°26'39"N	44°36'42"E
9	Sample-9	Majwer	Goal Madram	14	13°20'24"N	44°41'14.3"E
10	Sample-10	Mareeb	Mareeb	11	13°25'36"N	44°37'43"E
11	Sample-11	Dagran	Dagran	10	13°27'48"N	44°35'51"E
12	Sample-12	Ali Nusorah	Qaaf	12	13°25'12.9"N	44°39'34.9"E
13	Sample-13	Yaseen	Mucadium	28	13°28'19.06"N	44°35'23.67"E
14	Sample-14	Ahmed	Allugma'a	17	13°30'41.32"N	44°35'31.74"E
15	Sample-15	Alsaeed	Top asel	10	13°31'08.24"N	44°34'49.57"E
16	Sample-16	Abdulkareem	Habeel Alaf	13	13°28'01"N	44°35'44"E
17	Sample-17	Shatha'a	Shatha'a	6.8	13°34'23.27"N	44°32'59.5"E

3. Results and Discussion

The results demonstrated variations in the physical properties and fluoride content of the surface water sources, indicating that water quality fluctuates according to geographical location **(Table 1). Table 2** and **Figure 2** present the findings for the surface water samples within the study area. Turbidity values for the analyzed samples ranged from 0.2 to 2.69 NTU, with an average value of 1.37 NTU and a standard deviation of 0.85 NTU. The recorded temperature was 25.0 ºC, while pH levels ranged between 7.33 and 7.76, with an average of 7.48 and a standard deviation of 0.19. These findings fall within the permissible limits established by the **WHO** in 2017 **[32] .** Furthermore, the determination of fluoride in the study samples revealed significant differences among the surface water sources. Fluoride concentrations ranged from 1.1 mg/L to 5.7 mg/L, with an average of 2.57 mg/L and a standard deviation of 1.19.High fluoride concentrations were observed in most of the studied wells, primarily attributed to the geological strata (mineral composition) and physical properties, such as soil textures [**5;6;11;21**]. While fluoride levels in samples 3, 8, and 13 remained within the WHO permissible limits, concentrations in the remaining water samples exceeded these maximum thresholds. Consequently, the water from these other sources is deemed unsuitable for drinking and general human consumption. Fluoride is essential for dental protection, as moderate ingestion can reduce the risk of dental cavities; children require fluoride to safeguard newly forming teeth, while adults need it to prevent decay [**12**]. Nevertheless, the intake of water with excessive fluoride Concentrations (>1.5 mg/L) can lead to adverse impacts on human teeth and bones. Long-term consumption of fluoride-contaminated water may result in joint pain, skeletal fluorosis (which increases the risk of bone fractures), immobilization, and neurotoxicity [**1**].

Dissanayake [13] and Rehman et al. [19], categorized water into different classes based on fluoride concentration and its associated effects on skeletal and dental health. Accordingly, water samples from the study area were classified into six distinct categories [7;12].

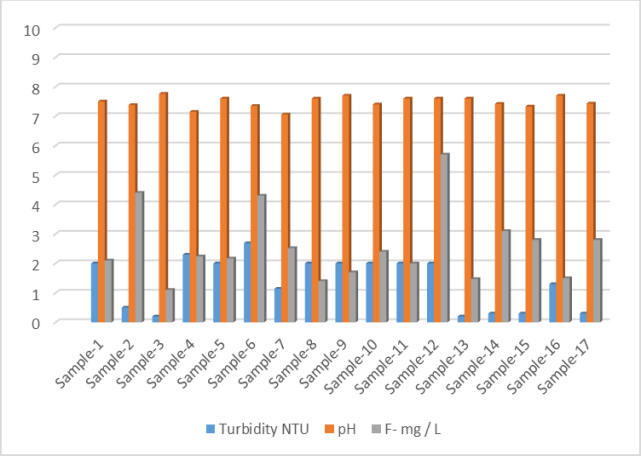

Figure 2: The turbidity, pH and fluoride content of the water samples in study area (at 25 °C)

Table 1: Location Details with latitude and longitude of surface wells samples collected from Al-Musaymir district in Lahij governorate.

Name of well	Village	Parameter	Turbidity	pH	Fluoride
		Unit	NTU	-	mg / L
		WHO guidelines	1-15	6.5-8.5	0.5-1.5
Fadhal Saeed	Al-Sarahn'a	Sample-1	2	7.5	2.1
Fara'a	Fara'a	Sample-2	0.5	7.38	4.4
Nakhela'a	Nakhela'a	Sample-3	0.2	7.76	1.1
Mutein	Nakhela'a	Sample-4	2.3	7.15	2.24
Qayif	Qaaf	Sample-5	2	7.6	2.17
Qaaf	Qaaf	Sample-6	2.69	7.35	4.3
Bashria	Bashria	Sample-7	1.14	7.06	2.52
Alhaqaf	Al-Musaymir Center	Sample-8	2	7.6	1.4
Majwer	Goal Madram	Sample-9	2	7.7	1.7
Mareeb	Mareeb	Sample-10	2	7.4	2.4
Dagran	Dagran	Sample-11	2	7.6	2
Ali Nusorah	Qaaf	Sample-12	2	7.6	5.7
Yaseen	Mucadium	Sample-13	0.2	7.6	1.47
Ahmed	Allugma'a	Sample-14	0.3	7.42	3.1
Alsaeed	Top asel	Sample-15	0.3	7.33	2.8
Abdulkareem	Habeel Alaf	Sample-16	1.3	7.7	1.5
Shatha'a	Shatha'a	Sample-17	0.3	7.43	2.8
Average			1.37	7.48	2.57
Standard deviation			0.85	0.19	1.19
Minimum			0.2	7.33	1.1
Maximum			2.69	7.76	5.7
Average ± SD			1.37±0.85	7.48±0.19	2.57±1.19

Table 2: The turbidity, pH and fluoride content of the water samples in study area (at 25 °C)

Classes	Fluoride Conc. (mg/L)	No. of samples	Percentage (%)	Impact on Human Health
Class 1	< 0.5	-	-	Conductive to dental caries
Class 2	0.5-1.5	3	17.65	Promotes development of strong bones and teeth
Class 3	**1.5-3**	**10**	**58.82**	**Promotes dental fluorosis in childre**n
Class 4	**3-5**	**3**	**17.65**	**Dental and mild skeletal fluorosis**
Calss 5	**5-10**	**1**	**5.88**	**Promotes crippling skeletal fluorosis**
Calss 6	>10	-	-	Crippling skeletal fluorosis, possibly cancer
Total		17	100 %	

The majority of the water samples—specifically 10 samples (58.82%)—fall into Class 3 (1.5–3.0 mg/L). Additionally, 3 samples (17.65%) were categorized as Class 4 (3.0–5.0 mg/L), 3 samples (17.65%) as Class 2 (0.5–1.5 mg/L), and 1 sample (5.88%) as Class 5 (5.0–10.0 mg/L). No samples fell within Class 1 (<0.5 mg/L) or Class 6 (>10.0 mg/L). These findings indicate that dental fluorosis has reached an alarming stage among the inhabitants of the study region.Table 4. shows the range of fluoride concentrations

In different parts of Yemen. It is obvious that fluoride levels in Yemen varies greatly. Although this variation could be attributed to the geological structures of these regions, only a comprehensive study can reveal the hidden causes and correlate these levels with the health of those living in these areas [2]. The regional hydrogeochemical investigation indicates that water-rock interaction is probably the main reason for the high concentration of ions in groundwater [5].

Table 3: Classification of drinking water in Al-Musaymir district an according to the concentration of fluoride and impact on human health

Area	Water sample type (surface/ground)*	Fluoride Conc. (mg/l) ranges, (average)	Higher than the WHO limits	Ref.
Al-Dhalia	Ground water	BDL- 9.46	31.25% (n=16)	[27]
Al-Dhalia	Surface/ground	0.60-13.30 (3.67)	66.7% (n=15)	[7]
Al-Dhalia basin	Ground water	0.31 to 18.30 (6.03)	71% (n=28)	[5]
Bir Nasser and Bir Ahmed (Lahij & Aden)	Ground water	0.015-2.4 (1.019)	20% (n=20)	[21]
Shara'a springs, Lahij	Surface water (Hot spring)	4.33-5.1	100% (n=8)	[26]
Kirsh springs, Lahij		6.17-7.63	100% (n=7)	[26]
Sana'a	Drinking water	0.446 - 5.023	35.62% (n=73)	[3]
Dhamar city	Drinking water	0.30-1.84	25% (n=16)	[2]
Al-Howban Basin Taiz	Drinking water	0.98 to 3.6 (1.65)	73% (n=33)	[9]
Rasyan Aquifer, Taiz	Ground water	0.1 to 6	71% (n=93)	[18]
Ghail Bawazeer, Hadhramaut	Tap water	2.34 to 2.46 (2.4)	100% (n=10)	[10]
Hidhran & Alburayhi Basin, Taiz	Drinking water	1.08 to 10.00	83.9 % (n=31)	[4]
Al-Musaymir district	Surface water	1.1-5.7 (2.57)	82.35% (n=17)	**This Study**

Conclusion

The results of turbidity, temperature and pH in all samples of drinking water were within WHO permissible limits, but the results expressed that fluoride concentration in 82.35% of samples were exceeded the maximum permissible limit for WHO, while 17.65% of the samples (3, 8 and 13) were found within the permissible limit by WHO. The difference in fluoride concentration between samples may be due to the difference at geographical locations as well as the depths of wells.

Recommendations:

It is recommending the government institutions and organizations to conduct a study of the soil and find out the reasons for increasing concentration of fluoride and make solutions. Fluoride poisoning can be prevented or minimized by using alternate water sources, improving the nutritional status of population at risk and removing excess fluoride (defluoridation).

Disclosure

The authors declare the conflicts of interest in their work.

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University of Aden Journal of Natural and Applied Sciences., vol.29(2) (2025) 47-54

مجلة جامعة عدن للعلوم الطبيعية والتطبيقية

Journal homepage: https://uajnas.adenuniv.com

بحث علمي

تقييم محتوى الفلوريد في مياه الشرب في مديرية المسيمير ، محافظة لحج ، اليمن

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https://doi.org/10.47372/uajnas.n2.a05

الملخص

تمثلت مشكلة الدراسة في وجود تدهور في خصائص مياه الشرب في مديرية المسيمير محافظة لحج، وظهور تسمم الاسنان بالفلور وهشاشة العظام عند الاطفال. الهدف من هذه الدراسة هو تحديد تركيز الفلورايد في مياه الشرب بمنطقة الدراسة، ومقارنتها بمعايير منظمة الصحة العالمية. تم جمع سبعة عشر عينة من مصادر مياه الشرب. تم قياس درجة الحرارة ودرجة الحموضة باستخدام الأجهزة الرقمية مباشرة بعد أخذ العينات في الحقل، بينما تم تحليل العكارة ومحتوى الفلوريد في مختبر المؤسسة المحلية للمياه والصرف الصحي بواسطة أجهزة المقياس الطيفي. أظهرت النتائج ان تركيز الفلورايد في معظم عينات الدراسة تجاوز الحدود المسموح بها من قبل منظمة الصحة العالمية. أوصت الدراسة المؤسسات الحكومية والمنظمات بإجراء دراسة للتربة والصخور لمعرفة أسباب زيادة تركيز الفلورايد وتقديم الحلول.

مفاتيح البحث

التسليم :5 /11/ 2025

القبول : 28 /3/**2026**

كلمات مفتاحية :

الفلورايد ، التحليل الطيفي ، جودة مياه الشرب ، مديرية المسيمير