

RESEARCH ARTICLE

MONITORING OF CALCIUM AND FLUORIDE IN DRINKING WATER ROUND AL-DHALEA DISTRICT, AL-DHALEA GOVERNORATE- YEMEN

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Abstract

Water is an essential for life, it provides humans with many useful salts and minerals, but if exceeds or decreases the permissible limit, it causes health risks. Many health problems appeared in the study area related to calcium and fluoride that present in drinking water. The study aimed to determine the amount of calcium and fluoride in drinking water to access healthy and safe drinking water, using palintest photometer 7500. The results were expressed that Fluoride concentration in Al-Dhalea district differed from one region to another according to the geographical location and the source of the water, also found the physical parameter in permissible limit except in turbidity in Thowbah piped water exceeded to 31 NTU. In spectroscopically parameter found the highest concentration of fluoride in Al-Raibi Hajr well, while the highest concentrations of calcium and total hardness in Al-Dawlah Habil Alsooq well. The study recommends the population to avoid drinking from polluted water and water that contains high concentrations of metals, because it is dangerous to health. The study also obtained that Al-Shalal water station is the best water between samples selected for analysis. Which most of its specifications correspond to Yemen parameter limit except a small concentration in some element.

Key Words: Calcium, Fluoride, total hardness, palintest photometer.

تحديد الكالسيوم والفلوريد في مياه الشرب بمديرية الضالع بمحافظة الضالع - اليمن

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المستخلص

الماء عنصر أساسي في الحياة، يقوم بتزويد الإنسان بالعديد من الأملاح والمعادن المفيدة، ولكنها إذا زادت أو نقصت عن الحد المسموح به تسبب خطراً على الصحة. ظهرت مشاكل صحية كثيرة في منطقة الدراسة تتعلق بعنصري الكالسيوم والفلورايد المتواجدة في مياه الشرب. هدفت الدراسة إلى تحديد تركيز الكالسيوم والفلورايد في مياه الشرب للحصول على مياه شرب صحية وآمنة باستخدام المقياس الطيفي Palintest 7500. أظهرت نتائج الدراسة أن تركيز الفلورايد في مديرية الضالع يختلف من منطقة إلى أخرى حسب الموقع الجغرافي ومصدر المياه، وجد أيضاً أن البارامترات الفيزيائية في الحد المسموح به ما عدا العكارة في مشروع مياه ثوبية تجاوزت الحد المسموح به إلى 31 NTU. في تحليل البارامترات الطيفية وجد أن أعلى تركيز للفلورايد في بئر الريبي حجر بينما أعلى تركيز للكالسيوم والقساوة الكلية للماء في بئر الدولة حبيل السوق. أوصت الدراسة السكان بتجنب الشرب من المياه الملوثة والمياه التي تحتوي على تركيزات من المعادن؛ لأنها تشكل خطورة على صحتهم، كما وجدت الدراسة إلى أن محطة مياه الشلال هي أفضل مياه من بين العينات المختارة للتحليل حيث تتوافق معظم مواصفاتها مع الحدود المسموح به في اليمن عدا تراكيز بسيطة في بعض العناصر.

Introduction:

Water is one of the main natural resources that God gave to man for the continuation of existence. (Ayebo, 2021) it is in continuous movement on, above, and below the surface of the earth. (Oni, 2020) it is one of the main important abiotic components of the environment, for human use is obtainable as surface and ground water. (JIMA, S., 2019) Access to a safe and reliable supply of drinking water is essential for the wellbeing of all human beings. However, the availability of fresh water is getting scarce let alone its quality, which becomes a major issue in world. (Idris, 2018) Even though water may be clear, it does not necessarily mean that it is safe for us to drink. must be considered Microbiological, Chemical and Physical parameters, Safe drinking water should be low in concentrations of toxic chemicals, Clear, Tasteless and colourless. (Oni, 2020) Yemen is a water-scarce country, situated in an arid region with no permanent rivers. The annual per capita share of renewable water resources does not exceed 150 cubic meters. The country's rapid population growth is putting more strain on water supplies while human development levels remain low, making it difficult to increase adaptive capacity and resilience to water shortages and other climate change related impacts. (United Nations, 2016) Water supply and sanitation in Yemen is characterized by many challenges as well as some achievements. A key challenge is severe water scarcity, especially in the Highlands, prompting The Times of London to write "Yemen could become the first nation to run out of water". (Asthana, 2009) In Yemen less than half the population living in rural areas has access to safe drinking water, another important cause of malnutrition in Yemen. Access to health facilities – a key determinant of both household food security status and the nutritional well-being of its women and children - is also greatly limited in rural areas. (United Nation, 2011)

Before taking samples from study area, had interview with number of persons and Specialized doctors, to know the problem that the study area suffers from it, they said there is a large spread of dental fluorosis and bone curvature due to the increased concentration of fluoride in some areas, while other areas suffer from kidney stones. Generally, the interview gave me an overall image of the study area and its threatening causes. So, it helped me for further analytical study by taking samples from chosen locations.

Geology of study area

The rocks found in Al-Dhalea district- Al-dhalea governorate from cretaceous age, which are known as sandstone. It also contains basalt, dacite and pyroclastic covering large parts of district, the area is also covered with acidic sediments such as granite rocks located in the southeastern part, and it consists of sand and gravels of different size. The ground water consists of two layers, upper aquifer and deeper aquifer. But this water drains quickly after the rainy season. (Al-Amry, 2020)

Drinking water sources in study area

The chief sources of water in general are rain water, sea water, ground water and surface water. The main drinking water sources in study area for the majority (72.4%) of households are either water tankers (trucks) or open wells (both protected and unprotected), while only 11.2% of households are using piped water. Whereas 16.4% using other sources such as: Bottled water, covered or uncovered rain water. Only 38.6% of households are using improved water sources and 21.9% are using

unimproved sources, while 39.5% are using unclassified sources (tankers, community points (Sabeel) and bottled water) Household which are not using bottled water have been asked for treatment of water before drinking. To determine the quality of drinking water in any water system, several parameters must be checked and water quality monitored, especially in open systems that are used for human and industrial purposes.

various institutions, associations, organizations and health agencies have proposed the standards at international level for acceptable potable water such as: World Health Organization (WHO), Indian Council of Medical Research (ICMR), Bureau of Indian Standards (BIS) and American Public Health Association (APHA) as follow:

Table (1): WHO, ICMR, BIS, and U.S. EPA Drinking Water Standard (WHO, 2011; ICMR, 1975; BIS, 2012, U.S. EPA, 2009)

Parameter		WHO	ICMR	BIS	EPA	Yemen limit
Colour	Desirable Limit	NG	NG	5 Colour units	5 Colour units	5 Colour units
	Permissible limit	NG	NG	15 Colour units	15 Colour units	15 Colour units
PH	Desirable Limit	7 – 8.5	7 – 8.5	6.5 – 8.5	6.5 – 8.5	6.5 – 8.5
	Permissible limit	6.5 – 9.2	6.5 – 9.2	NG	NG	NG
Turbidity	Desirable Limit	5 NTU	5 NTU	1 NTU	NG	1 NTU
	Permissible limit	25 NTU	25 NTU	5 NTU	NG	15 NTU
Calcium	Desirable Limit	75	75	75	75	75
	Permissible limit	200	200	200	200	200
Fluoride	Desirable Limit	0.7	1	1	1	0.5
	Permissible limit	1.5	1.5	1.5	105	1.5
Magnesium	Desirable Limit	30	50	30	NG	30
	Permissible limit	150	150	100	NG	150
Chloride	Desirable Limit	200	200	250	250	200
	Permissible limit	600	1000	1000	NG	600
Iron	Desirable Limit	0.3	0.1	0.3	NG	0.3
	Permissible limit	1.0	1.0	1.0	NG	1.0
Sulfate	Desirable Limit	200	200	200	250	200
	Permissible limit	400	400	400	450	400
Bicarbonate	Desirable Limit	500	500	500	NG	100
	Permissible limit	NG	NG	NG	NG	500

Parameter		WHO	ICMR	BIS	EPA	Yemen limit
Total Hardness	Desirable Limit	300	300	200	NG	100
	Permissible limit	500	600	600	NG	500
TDS	Desirable Limit	500	500	500	500	500
	Permissible limit	1500	1500	2000	1500	1500
Sodium	Desirable Limit	200	NG	NG	NG	200
	Permissible limit	400	NG	NG	NG	400

Materials and Method:

Study Area: The study area located in the southwest of Al-Dhalea District, the coordinate lies between latitude: 13° 41' 44" N and longitude: 44° 43' 52" E.

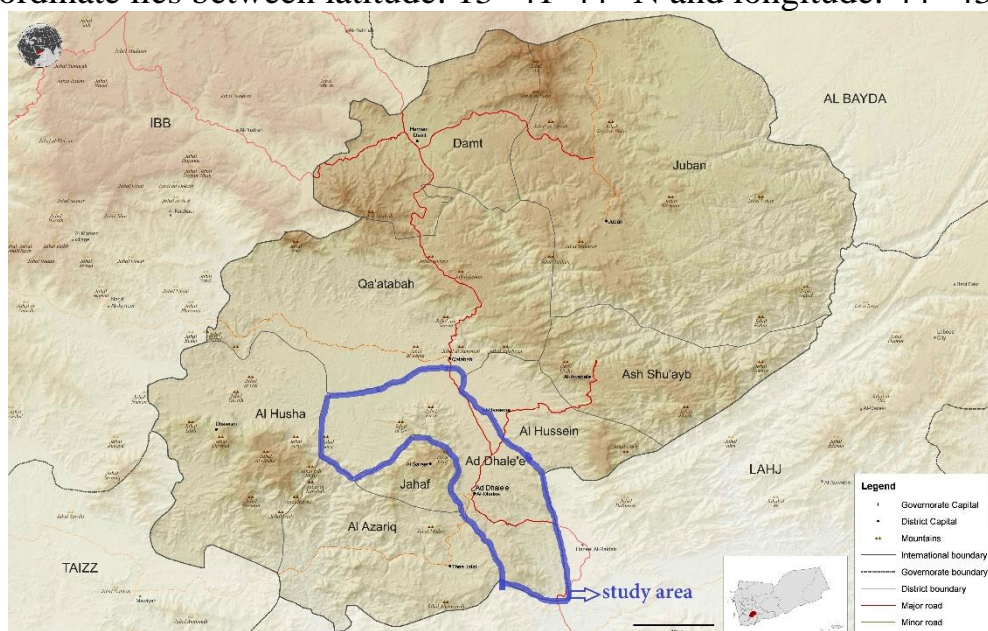


Fig. (1): Map of study area

Sample collection, preparation and physical parameter measurement: Thirty of drinking water samples were collected from several wells in multiple locations of the study area, surface and ground water. The samples were taken between July 11, 2021 to August 15, 2021. To determine the physical and spectroscopical parameters; samples were collected from the study area by bottles of 1500 ml capacity, each sample bottles were washed with the same well drinking water from which the sample was taken before filling to make the results more accurate and avoid any error in the results. the samples were analyzed for physical parameters such as: Turbidity, and PH. For spectroscopically parameters such as: Electrical Conductivity, Total Dissolved Salts, fluoride, sulphates, nitrate, iron, manganese, Phosphate, total alkalinity, bicarbonate, carbonate, total hardness, calcium, magnesium, chlorides, sodium, potassium, magnesium hardness, and potassium hardness. The materials used for executing the experiment for this thesis work are sampling bottles to take samples from the drinking water sources, pH meter, conductivity meter, digital turbidity meter and palintest photometer 7500.

For determination of spectroscopical parameter, Palintest Photometer 7500 was turned on, choose the specific wavelength for the type of examination to be analyzed by changing the specific filter, then zero the photometer by using sample blank (plain sample without adding tablet indicator) in cuvette. For the analysis 10 ml test tubes were filled with the water sample and the palintest water test tablets were added, after their solution was left to stand for the specified time to allow for full color development, for the determination of concentrations of any parameter; reading was taken directly from the photometer screen.

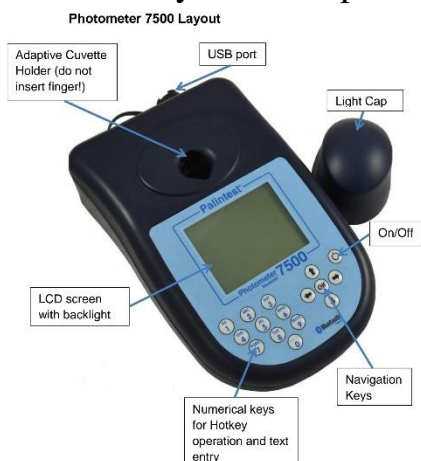


Fig (2): Palintest photometer 7500



Fig (3): Fill test tube with sample



Fig (4): conductivity meter

Results and discussion:

Results

results showed variations in the physical and spectroscopical parameters of drinking water in study area. Water quality varies from location to location, according to the geographical location and source of water. The table (4) shows the names of the wells, their numerical arrangement, and the results of the physical parameters. While the table (5) shows results of spectroscopical parameters of samples.

Table (4): name of wells and results of physical parameters of Al-Dhalea district

Sample code	Location	Turbidity	PH
		1 – 15 NTU	6.5-8.5
S1	Al-Shallal Water Station	0.92	7.76
S2	Al-Wa'arah	1.4	7.9
S3	Mohammad Muthanna Galas	1.25	8
S4	Thowbah piped water	31	7.6
S5	Al-Tafwah piped water	0.01	7.65
S6	Al-Demnah piped water	1.03	8.2
S7	Al-Mrkoolah piped water	1.8	7.75
S8	Aldhubyyat & Laghwal piped water	2.5	7.5
S9	bin La'ram Zubaid	11.6	7.55
S10	Al-Hmeera'	1.83	7.60
S11	Al-Houd Association	2.04	7.90
S12	Dhakhar piped water	24	7.75
S13	Al-Riyashi Al-Ushry	13	7.60
S14	Ali Abdullah Al-Jarba	1.52	7.45
S15	Al-Ribat Lakmat Salah	2.3	7.60
S16	Ba Abbad Ghool Sumeed	1.3	7.9
S17	Al-Sha'ab ground water	1.05	7.4
S18	Hezam Dhi-Herran	1.9	7.6
S19	Al-Dawasah Alsurafi	1.11	7.75
S20	Hkaref Ghool Sabolah	3.54	7.45
S21	Ali Mused Algleelah	5.52	7.7
S22	Al-areefah Alseelah	3.72	7.5
S23	Fathi Alghaimani	4.76	7.55
S24	Nabeel Muthanna Sanah	0.94	7.6
S25	Antar Al-Daragah	1.36	7.55
S26	Amed Kuraish Albajh	0.91	8.10
S27	Mohamed Kasem Bajah	1.2	7.90
S28	Al-Dawlah Habil Alsooq	1.54	7.75
S29	Aqmat Alewah Alshreefah	1.11	7.70
S30	Al-Raibi Hajr	1.23	7.80
Average		4.25	7.70
STD		7.01	0.20
Min		0.01	7.40
Max		31	8.2

Table (5): Results of spectroscopical parameters of Al-Dhalea district

Sample Code	Parameter									
	E. Conductivity	TDS	F-	SO4-2	NO3 -	Fe+ 2	Mn+ 2	PO4-3	T.alka	HCO3 -
S1	190	124	0.9	25	7.6	0.6	0.001	0.23	30	35
S2	1052	684	1.06	175	7.6	0.1	0.003	0.23	30	35
S3	1053	686	1.5	170	10.4	0.10	0.005	0.17	45	55
S4	1351	878	11.2	180	4.4	0.05	0.019	0.18	215	264
S5	1340	871	12	175	12	0.6	0.013	0.12	200	245
S6	857	557	0.52	79	62	0.100	0.002	0.14	245	300
S7	845	549	1.34	140	15.2	0.10	0.010	0.36	105	125
S8	890	579	1.5	72	16	0.15	0.006	0.13	310	380
S9	1390	904	4	185	11.2	0.6	0.018	0.18	60	75
S10	1109	721	0.27	118	10	0.05	0.004	0.10	295	360
S11	1500	975	0.79	185	60	0.20	0.005	0.24	35	40
S12	604	393	0.47	70	1.6	0.40	0.020	0.20	60	70
S13	655	426	0.4	58	8	0.65	0.008	0.15	230	280
S14	1710	1112	1.00	195	88	0.10	0.004	0.15	260	315
S15	4160	2704	1.15	195	350	0.1	0.001	0.13	240	295
S16	1320	858	1.11	185	0.4	0.05	0.002	0.12	370	450
S17	1205	783	0.52	170	96	0.05	0.001	0.14	250	305
S18	1065	692	0.95	195	8	0.1	0.005	0.13	270	330
S19	1945	1264	0.41	190	154	0.3	0.002	0.13	300	370
S20	1160	754	0.98	150	20	0.15	0.001	0.15	295	355
S21	3100	2015	0.74	195	46	0.10	0.005	0.10	285	350
S22	720	468	0.3	112	10	0.05	0.003	0.14	200	245
S23	1600	1040	0.65	195	134	0.1	0.008	0.13	195	240
S24	4820	3133	2.22	190	112	0.2	0.001	0.13	340	410
S25	1560	1014	0.48	150	104	0.1	0.003	0.11	350	420
S26	740	481	0.58	150	22	0.3	0.001	0.11	195	240
S27	1730	1125	11.4	190	0.8	0.15	0.011	0.17	285	350
S28	5580	3627	2.82	190	470	0.9	0.01	0.13	230	280
S29	1100	715	2.34	175	88	0.3	0.005	0.15	275	335
S30	1715	1115	13	180	9.2	0.4	0.012	0.28	60	70
Average	1602.20	1041.57	2.55	154.63	64.61	0.24	0.01	0.16	208.67	254.13
STD	1234.24	802.19	3.82	48.50	105.0	0.22	0.01	0.06	105.46	128.88
Min	190.00	124.00	0.27	25.00	0.40	0.05	0.00	0.10	30.00	35.00
Max	5580	3627	13	195	470	0.9	0.02	0.36	370	450
Yemen limits	450-2500	650-1500	0.5-1.5	200-400	45-50	0.3-1	0.1-0.2	0.4-5	150-500	150-500

Sample Code	Parameter								
	CO ₃ -2	T.Hard	Ca+2	Mg+2	Cl-	Na	K. hard	Ca. hard	Mg
S1	20	5	0.4	1	200	153	3.2	1	4
S2	15	340	19.2	71.2	425	217.4	2.3	48	292
S3	30	85	14	12	475	371.4	2.9	36	49
S4	130	620	23	137	475	209	9	58	562
S5	120	380	19	81	425	277	10.4	47	333
S6	150	340	56	48.5	450	286	1.6	141	199
S7	60	190	44	20	450	320	4	109	81
S8	190	520	144	39	475	246	4.2	361	159
S9	35	230	95	7.32	450	303	3.8	200	30
S10	180	390	93	38.3	475	321.2	4.3	233	157
S11	20	105	15	16.6	450	349	5.6	37	68
S12	35	80	19	8	450	316.4	2.9	47	33
S13	135	200	59	13	350	269	0.5	147	53
S14	155	760	170	80.5	475	172	3.4	430	330
S15	145	1000	180	134	450	37	2.4	450	550
S16	220	360	34	67	475	402	3.1	86	274
S17	150	450	102	48	475	298	3	254	196
S18	165	350	40	61	475	365	3.3	99	251
S19	180	520	65	87	475	298	2.6	163	357
S20	175	370	89	36	500	362	2	222	148
S21	170	800	83	144	375	100	1.9	208	592
S22	120	250	57	26	475	339	3.1	143	107
S23	115	640	150	63.4	425	165	2.5	380	260
S24	200	960	91	179	295	273	2.2	227	733
S25	210	550	134	52.4	425	256	3	335	215
S26	120	340	87	30	265	177	3.9	218	122
S27	170	60	10	8.3	475	561	11	26	34
S28	140	2350	246	423	305	27.3	4.3	616	1734
S29	165	370	112	22	475	349	4.7	281	89
S30	30	55	8	8.5	500	413	9.5	20	35
Average	125.00	455.67	75.29	65.43	429.67	274.42	4.02	187.43	268.23
STD	63.68	441.96	60.24	81.56	74.28	112.88	2.60	150.93	334.44
Min	15.00	5.00	0.40	1.00	200.00	27.30	0.50	1.00	4.00
Max	220	2350	246	423	500	561	11	616	1734
Yemen limits	150 - 200	100- 500	75- 200	30- 150	200- 600	200	20	50- 250	50- 250

Discussion

Comparing the average of physical parameters in Al-Dhalea District with Yemen limits as a reference show that parameters such as turbidity and PH within normal limit. Table (4) in results shows physical parameters for all samples, found PH within normal for all wells with average 7.70mg/l, STD 0.20, Minimum 7.40 mg/l and Maximum 8.2 mg/l, also the turbidity within normal with average 4.25 NTU, STD 7.01, Minimum 0.01 and Maximum 31 NTU Except in Thowbah piped water 31 NTU.

Table (6): Ave., STD, Min and Max for physical parameters in Al-Dhalea district.

Descriptive statistic	Parameter	Turbidity	PH
	Yemen limits	1 – 15 NTU	6.5-8.5
Average		4.25	7.70
STD		7.01	0.20
Min		0.01	7.40
Max		31	8.2

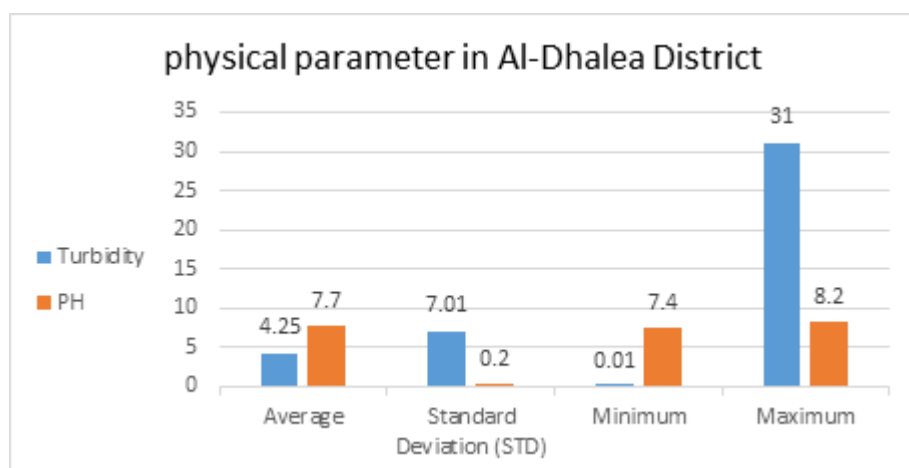


Fig. (5): graph of physical parameter in Al-Dhalea district

Discussion of Spectroscopical parameters

In this discussion, will be discuss the results of fluoride and calcium and their related parameter in drinking water that is total hardness. The table (5) in results shows spectroscopical parameters for all samples, also shows the descriptive statistics to average, standard deviation, minimum and maximum for spectroscopical parameters in the study area.

In this discussion, will discuss each parameter separately in order to know its concentration in each well of study area, and compare the results between the wells of the study area.

In Al-Dhalea district, the concentration of fluoride differed from one region to another according to the geographical location and the source of the water. Generally, the average concentration of fluoride exceeds WHO and Yemen limits that is 2.55 mg/l, STD 3.82 and minimum 0.27 mg/l (sample 10) and maximum 13 mg/l (sample

30). These results indicate that there are results in normal limit, also results below the normal limits, while others exceed the Permissible limit.

Table (5) indicates that there are 18 wells in Al-Dhalea district within the normal range of Yemen limits of fluoride concentration, samples are (1, 2, 3, 6, 7, 8, 11, 12, 14, 15, 16, 17, 18, 20, 21, 23, 25 and 26), also there are 4 wells less than minimum limits that are: (10, 13, 19 and 22) with concentrations (0.27 mg/l, 0.4 mg/l, 0.41 mg/l and 0.3 mg/l) respectively, these low concentrations lead to teeth decay. while 8 wells exceeded the permissible limit, some of them are less dangerous and contain fluoride between 1.5 to 4 mg/l, which are (9, 24, 28 and 29) with concentrations (4 mg/l, 2.22 mg/l, 2.82 mg/l, 2.34 mg/l) respectively. The remaining 4 wells contain fluoride at concentrations more than 4 mg/l, they are more dangerous to the population that are: (4, 5, 27 and 30) with concentrations (11.2 mg/l, 12.0 mg/l, 11.4 mg/l and 13.0 mg/l) respectively, these lead to skeletal fluorosis and curvature of bone.

Generally, the calcium concentration in most wells is less than the normal of WHO and Yemen limit. But due to the presence of high concentrations in some wells, it was found that the average concentration is within the critical minimum limit. the table (5) indicates the average concentration of calcium is 75.29 mg/l, STD 60.24, minimum 0.40 mg/l (sample 1) and maximum 246 mg/l (sample 28). indicates that there are results in normal limit, also results below the normal limits, while others exceed the Permissible limit.

The table (5) indicates that there are 13 wells In Al-Dhalea district within the normal range of Yemen limits of calcium concentration, samples are: (8, 9, 10, 14, 15, 17, 20, 21, 23, 24, 25, 26 and 29), but there are 16 wells less than normal limits that are: (1, 2, 3, 4, 5, 6, 7, 11,12, 13, 16,18,19, 22, 27, 30) with concentrations (0.4 mg/l, 19.2 mg/l, 14 mg/l, 23 mg/l, 19 mg/l, 56 mg/l and 44 mg/l, 15 mg/l, 19 mg/l, 59 mg/l, 34 mg/l, 40, mg/l, 57 mg/l, 10 mg/l, and 8 mg/l) respectively, in this district only one well exceed the Permissible limit with concentration 246 mg/l.

There is a relationship between calcium concentration in water and total water hardness according to the following equation:

$$\text{CaCO}_3 = 2.5 [\text{Ca}^{2+}] + 4.1 [\text{Mg}^{2+}]$$

Therefore, it is necessary to discuss results of total hardness as one of the water parameters affected by calcium.

In Al-Dhalea district, the table (5) indicates that the average concentration of total hardness lies in the normal limits of WHO and Yemen limits that is 455.67 mg/l, STD 441.96, minimum 5.0 mg/l (sample 1) and maximum 2350 mg/l (sample 28).

The table (5) indicates that there are 15 wells In Al-Dhalea district within the normal range of Yemen limits of total hardness concentration, samples are: (2, 5, 6, 7, 9, 10, 11, 13, 16, 17, 18, 20, 22, 26 and 29), but there are 5 wells less than normal limits that are: (1, 3, 12, 27 and 30) with concentrations (5 mg/l, 85 mg/l, 80 mg/l, 60 mg/l and 55 mg/l) respectively, While the remaining 10 wells are exceeded the Permissible limit which are: (4, 8, 14, 15, 19, 21, 23, 24, 25 and 28) with concentrations (620 mg/l, 520 mg/l, 760 mg/l, 1000 mg/l, 520 mg/l, 800 mg/l, 640 mg/l, 960, 550 mg/l and 2350 mg/l) respectively.

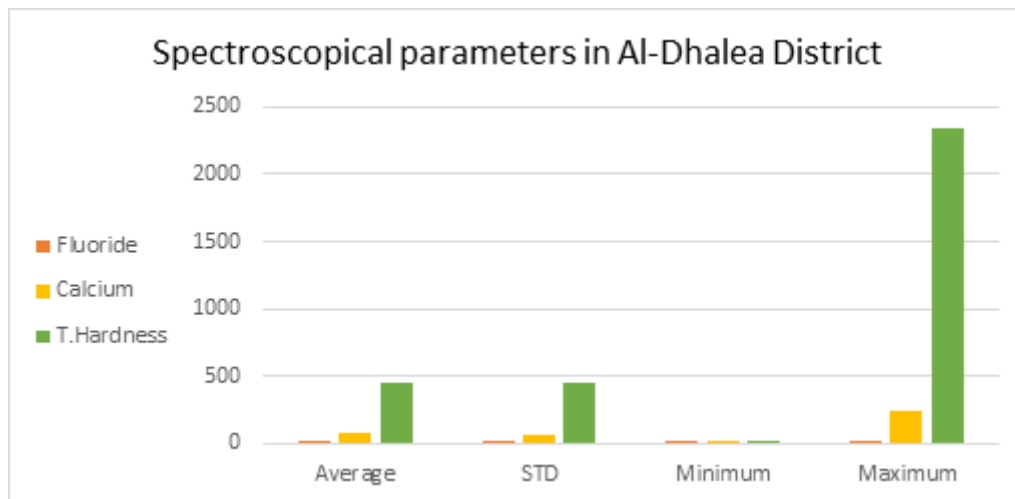


Fig (6): Graph of Spectroscopical parameter in Al-Dhalea district

Conclusion:

The results indicate that, the physical parameters of drinking water of Al-Dhalea district lies within normal of Yemen limits with PH average 7.70 and turbidity average 4.25 NTU, except turbidity of Thowbah piped water exceed the permissible Yemen limit to 31 NTU.

Fluoride concentration in Al-Dhalea district differed from one region to another according to the geographical location and the source of the water, the results show that the average concentration of fluoride exceed Yemen limit to 2.55 mg/l and STD 3.82. The study found that, Al-Raibi Hajr well contains the highest concentration of fluoride in study area with 13mg/l, while Al-Humeera' well contains the lowest concentration with 0.27 mg/l.

Calcium concentration in most wells less than normal limit but the average concentration lies in critical minimum limit 75.29 mg/l. Al-Dawlah Habil Alsooq well contains the highest concentration of calcium with 246mg/l, while Al-Shalal water station contains the lowest concentration with 0.40 mg/l.

Total hardness in drinking water of Al-Dhalea district has average in the normal of Yemen limit with 455.67 mg/l. Al-Dawlah Habil Alsooq well contains the highest concentration of total hardness, while Al-Shalal water station contains the lowest concentration with 5.0 mg/l.

The study recommends the population to avoid drinking from polluted water and water that contains high concentrations of metals, because it is dangerous to health. The study also obtained that Al-Shalal water station is the best water between samples selected for analysis. Which most of its specifications correspond to Yemen parameter limit.

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