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Chemical Analysis of Drink Water Samples for some Water Purification and Treatment Stations in El-Beida City - Libya and Compared with Residential and Mineral Water

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ABSTRACT

This study was conducted in the city of El-Beida-Libya on different samples from 11 drinking water purification and treatment stations, compared with the source water (residential water) and some of the most popular mineral water samples in the Libyan local markets. During this work, a number of chemical properties of the studied samples were examined, such as pH, Electric Conductivity (EC) (µS/cm),Total Dissolved Solids (TDS) (mg/l), Alkalinity (as HCO3-) (mg/l), Total Hardness (TH) (mg/l), Ca++(mg/l), Mg++ (mg/l), Na+(mg/l), K+ (mg/l), Cl- (mg/l) and NO3- (mg/l). The results obtained in the current study indicate that there are variation among stations. Whereas the pH values were ranged between (5.99 - 7.48), EC values were ranged (10.03 – 590 µS/cm), TDS values were ranged (5 - 283.33), Alkalinity (as HCO3-) values were ranged (44.73- 390.40 mg/l), Total hardness values were ranged (8.01-248.20 mg/l), Ca++ values were ranged (3.2-99.42 mg/l), Mg++ (1.92-59.52 mg/l), Na+ (1.92-23.24 mg/l), K+ (0.03-1.95 mg/l), Cl- (9.46-56.74 mg/l) and NO3- (6.33-12.17 mg/l). Most of the parameters analyzed in this study were within the guidelines given by the World Health Organization (WHO) and the Libyan National Centre for Standardization and Metrology (LNCSM) for drinking water while few others were not. Overall, the water from all the locations was found to be safe as drinking water except for the sample number S8 (Al Nabaa for drinking water purification and treatment), which is considered poor quality in terms of chemical properties specifications.

التحليل الكيميائي لعينات مياه الشرب لبعض محطات تنقية ومعالجة المياه بمدينة البيضاء - ليبيا ومقارنتها بالمياه السكنية والتجارية

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الكلمات المفتاحية:
مياه الشرب
التحليل الكيميائي
المياه السكنية
المياه التجارية
محطات المعالجة

الملخص

أجريت هذه الدراسة في مدينة البيضاء الليبية على عينات مختلفة من 11 محطة تنقية ومعالجة لمياه الشرب ، مقارنة بمصدر المياه (مياه سكنية) وبعض عينات المياه المعدنية الأكثر تداولا في الأسواق المحلية الليبية. خلال هذا العمل ، تم فحص عدد من الخصائص الكيميائية للعينات المدروسة ، مثل الأس الهيدروجيني ، التوصيل الكهربائي () (EC ميكرو سيمنز / سم) ، إجمالي المواد الصلبة الذائبة (TDS) (مجم / لتر) ، القلوية HCO3- (مجم / لتر) ، العسرة الكلية (TH) (مجم / لتر) ، Ca++ (مجم / لتر) ، Mg++ (مجم / لتر) ،Na + (مجم / لتر) ، K+ (مجم / لتر) ، Cl- (مجم / لتر)) و NO3- (ملغم / لتر). النتائج التي تم الحصول عليها في الدراسة الحالية تشير إلى وجود تباين بين المحطات. حيث تراوحت قيم الأس الهيدروجيني بين (5.99 - 7.48) ، تراوحت قيم EC بين (10.03 – 590 ميكرو سيمنز / سم) ، تراوحت قيم TDS بين (5 - 283 مجم / لتر) ، تراوحت قيم القلوية 44.73 - 390.40 HCO3-) مجم / لتر) ، تراوحت قيم العسرة الكلية (8.01- 248.20 مجم / لتر) ، وتراوحت قيم Ca ++ بين) 3.2 - 99.42 مجم / لتر) ، 59.52 -1.92) ++ Mg مجم / لتر) ، 23.24 - 1.92) Na+ مجم / لتر) ، 1.95 -0.03) K+ مجم / لتر) ، 56.74 -9.46) Cl- مجم / لتر) ، 6.33 -2.17) NO3- مجم / لتر). كانت معظم المعلمات التي تم تحليلها في هذه الدراسة ضمن

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المبادئ التوجيهية التي قدمتها منظمة الصحة العالمية (WHO) والمركز الوطني الليبي للمواصفات والمقاييس (LNCSM) لمياه الشرب في حين أن القليل منها لم يكن كذلك. بشكل عام ، وجد أن المياه من جميع المواقع آمنة للشرب باستثناء العينة رقم 8 والتي تعتبر ذات نوعية رديئة من حيث مواصفات الخواص الكيميائية.

Introduction

Potable water is man's most basic requirement for survival. Water maintains body temperature and acts as the foundation for body fluids and metabolism [1]. Water is a good solvent because it readily absorbs contaminants, changing the taste, color, and aroma. Water's regular functioning and qualities are harmed when it is polluted, its normal functioning and properties are affected [2]. Continual improvement of water quality for drinking, domestic usage, personal cleanliness, and specific medical situations is one of the world's top issues. Worldwide waterborne diseases are the cause of death and suffering of millions of people, especially, children in developing countries, where polluted water kills about 3900 children every day [3]. One of the most essential factors in improving a community's human health by reducing the spread of water-borne disease is the availability of high-quality drinking water [4]. Elevated quantities of nonessential elements in drinking water can induce morphological deformities, reduced growth, increased mortality, and mutagenic effects [5-7]. Contaminants are chemicals that dissolve in water, rendering it unfit for human consumption. Because pure water is tasteless, colourless, and odourless, some contaminants can be easily discovered by examining the taste, odour, and turbidity of the water. Most, however, are difficult to detect and require testing to determine whether or not water is contaminated [8]. The Directive requires that the majority of the parameters chosen for analysis be physicochemical (such as pH, EC, and TDS) and chemical properties related to the treatment of water and its hardness (such as Cl^-, Na^+ ,K^+, Ca^{+2}, and Mg+2, and NO_3^-), as well as Total hardness and Total alkalinity. In the Libyan city of Alkoms a physiochemical study was conducted on six local brands of bottled drinking water. The results were compared with both Libyan and WHO standards. Various physical and chemical properties were studied. The pH, EC, Na, K, and Mg levels were in the acceptable range comparing with both Libyan and WHO limits, whereas calcium levels were up to four times as high as Libyan and WHO limits [9] .The purpose of this study was to investigate the extent of ions concentration in drinking water samples from drinking water purification and treatment stations, comparing these results with commercial and domestic water and their compliance with the guidelines of the WHO and LNCSM.

Materials and Methods

1. Sampling

The samples were collected (triplicate) in polyethylene plastic containers of 500 ml capacity from eleven stations dispersed in most residential areas of the Libyan city of El-Beida.. The collected samples were labeled with a date and code, then stored at 4° C until the analysis. Some tests were carried out in the field, such as pH, EC, and TDS. The samples were numbered from 1 to 15 against their locations and sources as shown in (Table 1). The samples from number 1 to 11 are from drink water purification and treatment stations, while the samples number 12 and 13 are mineral water, whereas the samples number 14 and 15 are residential water.

Table 1: Drinking water samples collection.

Number	Name Station	Locations	Source
1	Al-Saqi for purify drinking water	New El-bieda district, Farag Abdel Atti Street	Water locally canned
2	AlKawthar for drinking water purification and treatment	New El-bieda district, Marhaba hotel Street	Water locally canned
3	Fayez for drinking water purification	New El-bieda district, Al Guds Street	Water locally canned
4	Al Shallal for drinking water purification and treatment	New El-Bieda district, Al Zawai Street.	Water locally canned
5	Tabarak for drinking water purification and treatment	Jewels Mall Street	Water locally canned
6	AlMaa Alatheb for water purification	Al-Talhi Street	Water locally canned
7	AlWaha for Drinking Water Purification	Rwefa' and Maad Street	Water locally canned
8	Al Nabaa for drinking water purification and treatment	Highway Ring Road	Water locally canned
9	Al-Naeem for drinking water purification and treatment	El-Beida Centre - Administrative and Service Offices	Water locally canned
10	Al Ghadeer for Drinking Water purification	The South of El-Bieda - Al Khansa District	Water locally canned
11	Al Kufra for drinking water purification	Old market district	Water locally canned
12	AlHaya	Life Mall Shop - New El-Bieda District	Mineral water (MW)
13	AlSafia	Life Mall Shop - New El-Bieda District	Mineral water (MW)
14	Residential House	Jenin District	Residential water (RW)
15	Residential Flat	New El-bieda district,	Residential water (RW)

2. Analytical Measurements

pH was measured using digital pH meter with combined electrode. (Model Metrohm, pH Lab 827) [10]. EC was determined by Electric Conductivity meter (Model Metrohm, pH Lab 827 [10]. TDS was determined by Total Dissolved Salt meter (Model Metrohm, pH Lab 827.) [10]. Total alkalinity was estimated by titration with 0.02 N sulphuric acid and using phenolphthalein indicator in the case of carbonates and methyl orange indicator in the case of bicarbonate [10]. Total hardness, Calcium and Magnesium were measured by EDTA titration method [10]. Chloride was determined by titration using Mohr Method, where titration is done using 0.01 N silver nitrate ($AgNO_3$) solution, using 5% potassium chromate (K_2CrO_4), and titration until reaching the endpoint [11].The nitrate concentration was determined using the turbidity spectrophotometric technique wavelength of 410 nm [12]. Sodium and Potassium ions were measured by Flame photometer model (Jenway – PFP7) England (UK) [13].

3. Statistical analysis

Statistical analysis was used through the program statistical package for social sciences (SPSS) version 24, to calculate some descriptive statistics such as standard error(SE), Average, standard deviation (SD) and coefficient variance percentage (CV %). As well the indicative statistics analysis was also examined through a test of significant values (p) which results of the research were considered significant if were the calculated significant values $p \leq 0.05$ (α was chosen to be 0.05). For comparison of means, ANOVA test and Post Hoc were done.

Results and Discussion

1. pH.

pH is one of the most significant water quality metrics. The acidity or alkalinity of water is measured using the pH scale. If the pH of a sample is less than 7.0, it is called acidic. Meanwhile, if the pH is greater than 7.0, it is alkaline. Corrosion of metal pipes and the plumbing system can be caused by acidic water [14]. The normal drinking water pH range indicated by World Health Organization (WHO) (6.5-8.5) [15] and the Libyan National Center for Standardization and Metrology (LNCSM) (6.5-8.5) [16] (Table 13). The pH values of all the drinking water samples are found to be in the range between 5.99 and 7.24 (Table 2), where the sample No 8 shows the lowest value of pH, while the sample No 1 and 15 for the source water appear the highest values. (Table 2). The measured pH for the samples No.12 and 13 are 6.34 and 6.64 respectively. This is nearly identical to the pH listed on the container's label by the manufacturer. This means the manufacturer did not include any inaccurate information on the label. The pH of drinking water samples has no immediate direct effects on human health, but it does have some indirect effects on human health by affecting other water quality characteristics such as metal solubility and pathogen survivability [17]. At the level of the sites in (Table 2), we found that the lowest values recorded at the site (8) with an average concentration (5.99). This may be due to the impact of pollution from source at this station or because of the inaccuracy of the devices used in water purification. ANOVA and post hoc testing in (Table 2) show that there was significant differences with a statistical significance for the pH with the other sites ($p<0.05$) where the value of (Sig=0.000). This indicates that there is a difference for the mean pH between the fifteen sites, as a result of the difference, these sites of each other in kind of water source they're affected by sources of pollution. In general, the values of pH recorded in some study sites exceed permissible limits for international standards of drinking water are (6.5-8.5) of both WHO and LNCSM [15,16].

Table 2: Average of pH in water samples with standard eviation, standard error and coefficient variance values.

No	Con 1	Con 2	Con 3	S.E	Average	SD	CV %
1	7.1	7.26	7.36	0.08	7.24^{b}	0.13	1.81
2	7.08	7.16	7.2	0.04	7.15^{bc}	0.06	0.85
3	6.69	6.6	6.53	0.05	6.61^{h}	0.08	1.21
4	6.75	6.83	6.88	0.04	6.82^{def}	0.07	0.96
5	6.79	6.79	6.79	0.00	6.79^{efg}	0	0
6	6.61	6.69	6.72	0.03	6.67^{fgh}	0.06	0.85
7	6.35	6.39	6.41	0.02	6.38^{i}	0.03	0.48
8	6	6	5.97	0.01	5.99^{j}	0.08	0.29
9	6.33	6.4	6.42	0.03	6.38^{i}	0.05	0.74
10	6.64	6.7	6.75	0.03	6.70^{fgh}	0.06	0.82
11	6.84	6.93	6.95	0.03	6.91^{de}	0.06	0.85
12 MW	6.37	6.34	6.32	0.01	6.34^{i}	0.03	0.40
13 MW	6.59	6.64	6.68	0.03	6.64^{gh}	0.05	0.68
14 RW	6.93	6.98	7	0.02	6.97^{cd}	0.04	0.52
15 RW	7.41	7.53	7.51	0.04	7.48^{a}	0.06	0.86

For a given pH value, mean concentrations followed by the same letter are not significantly different.($p<0.05$).

2. Electric Conductivity (EC)

It is known that electrical conductivity is a numerical term for the portability of an aqueous solution to carry an electric current. This portability depends on the type and presence of ions and their concentration, the movement, and equivalence of ions, and the temperature of the solution [18]. Pure water is a poor conductor of electricity, but increasing salt in it increases the amount of electrical conductivity, so water conductivity is sometimes used to indicate the extent of the purity or contamination of water because the conductivity is directly proportional with the concentration of dissolved solids [19]. The results shown in the (Table 3) in the current study indicate that the electric conductivity (EC) values range from (10.03 – 310.33 µs/cm) in the treatment and purification water stations. The lowest values recorded at the station (8) with an average concentration (10.03 µs/cm). This may be due to the inaccuracy and calibration of the analysis equipment in this station, which lead to a very significant decrease in the value of electrical conductivity. For the samples No. 12 and 13, the measured EC are 38.4 µs/cm and 86.33 µs/cm respectively. This is nearly identical to the EC stated on the container's label by the manufacturer. This means the manufacturer did not include any inaccurate information on the label. The measured EC for the samples No.14 and 15 are 590 µs/cm and 571 µs/cm respectively. This is as a result of the fact that these are the sites of residentail water that comes directly from groundwater, which contains a high percentage of dissolved salts, which leads to an increase in electrical conductivity. Human health is not directly affected by conductivity. It's utilized for several purposes, including determining the mineralization rate (the presence of minerals like potassium, calcium, and salt) and measuring the amount of chemical reagents required to treat the water [20]. ANOVA and post hoc testing in (Table 3) show that there were significant differences with a statistical significance for the EC with the other sites ($p<0.05$) where the value of (Sig=0.000). This indicates that there is a difference for the mean EC between the fifteen sites, as a result of the difference these sites of each other in type of water source they are affected by sources of pollution. In general, the values of electrical conductivity (EC) recorded in this study did not exceed permissible limits for international standards of drinking water for each of the WHO (2300 µs/cm) [15] and LNCSM (2033 µs/cm) [16].

Table 3: Average of EC µS/cm in water samples with standard deviation, standard error and coefficient variance values.

No	Con 1	Con 2	Con 3	S.E	AVERAGE	SD	CV %
1	314	310	307	2.03	310.33^{c}	3.51	1.13
2	167.2	165.5	165.1	0.64	165.93^{d}	1.12	0.67
3	34.1	34	34.2	0.058	34.1^{k}	0.1	0.29
4	138.6	137.1	137.1	0.50	137.6^{f}	0.87	0.63
5	47	46.8	46.5	0.23	46.^{77j}	0.25	0.54
6	79.6	78.3	78.1	0.47	78.67^{i}	0.814	1.04
7	74.2	73.9	73.7	0.15	73.93^{i}	0.25	0.34
8	10.1	10.2	9.8	0.12	10.03^{l}	0.21	2.07
9	72.9	72.7	72.3	0.18	72.63^{i}	0.31	0.42
10	100.4	99.1	98.5	0.56	99.33^{g}	0.97	0.98
11	157.4	155.1	154.8	0.82	155.77^{e}	1.42	0.91
12 MW	38.8	38.3	38.1	0.21	38.4^{k}	0.36	0.94
13 MW	86.8	86.1	86.1	0.23	86.33^{h}	0.40	0.47
14 RW	595	589	586	2.65	590^{a}	4.58	0.78
15 RW	577	566	570	3.21	571^{b}	5.57	0.98

For a given EC value, mean concentrations followed by the same letter are not significantly different.($p<0.05$)

3. Total dissolved solids (TDS)

TDS is a term used to describe the amount of Total Dissolved Solids. The inorganic matter and small amounts of organic matter that are present as solutions in water are referred to as TDS [21]. The results in the (Table 4) in our study indicate that the Total dissolved solids (TDS) values range from (5 - 148 mg/l) in treatment and purification water stations. At the level of the treatment water stations in (Table 4), we found that the lowest values recorded at the station (8) with an average concentration (5 mg/l). This may be due to the inaccuracy and calibration of the analysis equipment in this station, which lead to a very significant decrease in the value of Total dissolved solids (TDS). For the samples No.12 and No.13, the measured TDS are 18 mg/l and 41 mg/l respectively. This is nearly identical to the TDS stated on the container's label by the manufacturer. This means the manufacturer did not include any inaccurate information on the label. The measured TDS for the samples No.14 and 15 are 283.33 mg/l and 272.33 mg/l respectively. This indicated that these are the sites of home water that comes directly from groundwater, which contains a high percentage of dissolved salts, which leads to an increase in TDS. ANOVA and post hoc testing in (Table 4) show that there was significant differences with a statistical significance for the TDS with the other sites ($p<0.05$) where the value of (Sig=0.000). This indicates that there is a difference for the mean EC between the fifteen sites, as a result of the difference these sites of each other in kind of water source they're affected by sources of pollution.

In general, the values of Total dissolved solids (TDS) recorded in this study did not exceed permissible limits for international standards of drinking water for each of the WHO (1000 mg/l) [15] and LNCSM (1000 mg/l) [16].

Table 4: Average of TDS mg/l in water samples with standard deviation, standard error and coefficient variance values.

No	Con1	Con 2	Con 3	S.E	AVERAGE	SD	CV %
1	150	148	146	1.15	148^{c}	2	1.35
2	81	79	78	0.88	79.33^{d}	1.53	1.93
3	16	16	16	0.00	16^{k}	0	0
4	66	65	65	0.33	65.33^{f}	0.58	0.89
5	22	22	22	0.00	22^{j}	0	0
6	38	37	37	0.33	37.33^{i}	0.58	1.55
7	35	35	35	0.00	35^{i}	0	0
8	5	5	5	0.00	5^{l}	0	0
9	35	34	34	0.33	34.33^{i}	0.58	1.68
10	48	47	46	0.58	47^{g}	1	2.13
11	75	74	73	0.58	74^{e}	1	1.35
12 MW	18	18	18	0.00	18^{k}	0	0
13 MW	41	41	41	0.00	41^{h}	0	0
14 RW	285	284	281	1.20	283.33^{a}	2.08	0.73
15 RW	275	270	272	1.45	272.33b	2.52	0.92

For a given TDS value, mean concentrations followed by the same letter are not significantly different.($p<0.05$)

4. Total alkalinity

Alkalinity (as HCO_{3}^{-}) is not a pollutant. It is a total measure of the substances in water that have acid neutralizing ability [22]. The results shown in the (Table 5) indicate that the total alkalinity values range from (44.73 - 207.4 mg/1) in treatment and purification water stations. At the level of the treatment water stations in (Table 5), we found that the lowest values recorded at the station (8) with an average concentration (44.73 mg/l). This may be due to the inaccuracy and calibration of the analysis equipment in this station, which lead to a very significant decrease in the value of total dissolved solids (TDS). The measured total alkalinity for the samples No.12 and 13 are 69.13 mg/l and 65.07 mg/l respectively. This is nearly identical to the Total alkalinity stated on the container's label by the manufacturer. This means the manufacturer did not include any inaccurate information on the label. For the samples No.14 and 15, the measured total alkalinity are 378.2 mg/l and 390.4 mg/l respectively. This is as a result of the fact that these are the sites of home water that comes directly from groundwater, which contains a high percentage of dissolved salts, which leads to an increase in total alkalinity. ANOVA and post hoc testing in (Table 5) show that there was significant differences with a statistical significance for the Total alkalinity with the other sites ($p<0.05$) where the value of (Sig=0.000). This indicates that there is a difference for the mean Total alkalinity between the fifteen sites, as a result of the difference these sites of each other in kind of water source they're affected by sources of pollution. In general, the values of Total alkalinity recorded in some study sites exceed permissible limits for international standards of drinking water of the WHO (200 mg/l) [15].

Table 5: Average of Total alkalinity mg/l in water samples with standard deviation, standard error and coefficient variance values.

No	Con 1	Con 2	Con 3	S.E	AVERAGE	SD	CV %

1	207.4	207.4	207.4	.00	207.4^{b}	0	0
2	146.4	134.2	146.4	4.00	142.33^{c}	7.04	4.95
3	48.8	48.8	48.8	.00	48.8^{fg}	0	0
4	134.2	158.6	146.4	7.04	146.4^{c}	12.2	8.33
5	48.8	85.4	61	10.76	65.07^{efg}	18.64	28.64
6	97.6	97.6	73.2	8.13	89.47^{defg}	14.09	15.75
7	85.4	85.4	73.2	4.07	81.33^{defg}	7.04	8.66
8	61	36.6	36.6	8.13	44.73^{g}	14.09	31.49
9	109.8	73.2	109.8	12.20	97.6^{cdef}	21.13	21.65
10	85.4	97.6	122	10.76	101.67^{cde}	18.64	18.33
11	122	122	109.8	4.07	117.93^{cd}	7.04	5.97
12MW	61	61	85.4	8.133	69.13^{defg}	14.09	20.38
13MW	61	73.2	61	4.07	65.07^{efg}	7.04	10.83
14 RW	353.8	414.8	366	18.64	378.2^{a}	32.28	8.53
15 RW	378.2	427	366	18.64	390.4^{a}	32.29	8.27

For a given total alkalinity value, mean concentrations followed by the same letter are not significantly different.($p<0.05$)

5. Total hardness

Hardness caused by calcium and magnesium is usually indicated by precipitation of soap scum and the need for excess use of soap to achieve cleaning. Consumers are likely to notice changes in hardness. Public acceptability of the degree of hardness of water may vary considerably from one community to another [15]. The water hardness ($CaCO_3$) depends on anions such as, bicarbonate, sulphate and chloride and major cations, such as calcium and magnesium, which are all below the permissible limits [22]. The results of the Total Hardness (TH) shown in the (Table 6) indicate that values range from (8.01 - 140.11 mg/l) in treatment and purification water stations. The lowest values recorded at the station (8) with an average concentration (8.01 mg/l). This may be due to the inaccuracy and calibration of the analysis equipment in this station, which lead to a very significant decrease in the value of Total hardness. The measured total alkalinity for the samples No.12 and 13 were 29 mg/l and 26.69 mg/l respectively. This is nearly identical to the Total hardness stated on the container's label by the manufacturer. This means the manufacturer did not include any inaccurate information on the label. The measured total hardness for the samples No.14 and 15 were 248.20 mg/l and 210.84 mg/l respectively. This is as a result of the fact that these are the sites of home water that comes directly from groundwater, which contains a high percentage of dissolved salts, which leads to an increase in total hardness. ANOVA and post hoc testing in (Table 6) show that there were significant differences with a statistical significance for the Total hardness with the other sites ($p<0.05$) where the value of (Sig=0.000). This indicates that there is a difference for the mean Total hardness between the fifteen sites, as a result of the difference these sites of each other in type of water source they are affected by sources of pollution. In general, the values of Total hardness recorded in this study did not exceed permissible limits for international standards of drinking water are (500 mg/l) for both WHO and LNCSM [15,16].

Table 6: Average of Total hardness mg/l in water samples with standard deviation, standard error and coefficient variance values.

No	Con 1	Con 2	Con 3	S.E	AVERAG	SD	CV %
1	140.11	140.11	140.11	0.00	140.11^{c}	0	0
2	68.05	84.07	72.06	4.81	74.73^{d}	8.33	11.15
3	20.02	20.016	20.02	0.00	20.02^{gh}	0	0
4	60.09	60.05	68.05	2.67	62.72^{de}	4.62	7.37
5	20.02	32.03	24.02	3.53	25.35^{fgh}	6.11	24.12
6	32.03	40.032	32.03	2.67	34.69^{fg}	4.62	13.32
7	36.03	24.02	36.03	4.00	32.03^{fg}	6.93	21.65
8	8.01	8.01	8.01	0.00	8.01^{h}	0	0
9	48.04	48.04	48.04	0.00	48.04^{ef}	0	0
10	36.03	52.04	44.04	4.62	44.04^{ef}	8.01	18.18
11	60.05	72.06	60.05	4.00	64.05^{de}	6.93	10.83
12 MW	20.02	40.03	28.02	5.82	29.36^{fgh}	10.1	34.32
13 MW	24.02	32.03	24.02	2.67	26.69^{fgh}	4.62	17.32
14 RW	248.20	248.20	248.20	0.00	248.20^{a}	0	0
15 RW	228.18	188.15	216.17	11.9	210.84^{b}	20.5	9.74

For a given TH value, mean concentrations followed by the same letter are not significantly different.($p<0.05$)

6. Calcium (Ca^{++})

This is the most significant and abundant element in the human body, and an adequate intake is essential for normal growth and health. The maximum daily requirement is in the range of 1 to 2 grams, which is primarily derived from dairy products. There is some evidence that places supplied by a public water supply with a high degree of hardness, the principal constituent of which is calcium, have a lower incidence of heart disease, implying that the element's presence in a water supply is advantageous to health [23]. Calcium (Ca^{++}) is dissolved easily out of almost all rocks and is, consequently, detected in most waters [21]. The results shown in (Table 7) in the current study indicate that the calcium values range from (3.2 - 56.12 mg/l) in treatment and purification water stations. At the level of the treatment water stations in (Table 3.6), we found that the lowest values recorded at the station (8) with an average concentration (3.2 mg/l). This may be due to the inaccuracy and calibration of the analysis equipment in this station, which lead to a very significant decrease in the value of calcium. For the samples No.12 and 13 (MW), the measured Calcium are 11.76 mg/l and 10.69 mg/l respectively. This is nearly identical to the Calcium stated on the container's label by the manufacturer. This means the manufacturer did not include any inaccurate information on the label. The measured calcium For the samples No.14 and 15 were 99.42 mg/l and 84.45mg/l respectively. This is as a result of the fact that these are the sites of home water that comes directly from groundwater, which contains a high percentage of dissolved salts, which leads to an increase in Calcium. ANOVA and post hoc testing in (Table 7) show that there were significant differences with a statistical significance for the Calcium with the other sites ($p<0.05$) where the value of (Sig=0.000). This indicates that there is a difference for the mean Calcium between the fifteen sites, as a result of the difference these sites of each other in kind of water source they are affected by sources of pollution. In general, the values of Calcium recorded in this study did not exceed permissible limits for international standards of drinking water for each of the WHO (200 mg/l) [15].

Table 7: Average of Calcium (Ca^{++} mg/l) in water samples with standard deviation, standard error and coefficient variance values

No	Con 1	Con 2	Con 3	S.E	AVERAGE	SD	CV %
1	56.12	56.12	56.12	0.00	56.12^{c}	0	0
2	27.26	33.67	28.86	1.93	29.93^{d}	3.34	11.15
3	8.02	8.02	8.02	0.00	8.02^{gh}	0	0
4	24.05	24.05	27.26	1.07	25.12^{de}	1.85	7.37
5	8.02	12.83	9.62	1.41	10.16^{fgh}	2.45	24.12
6	12.83	16.04	12.83	1.07	13.90^{fg}	1.85	13.32
7	14.43	9.62	14.43	1.60	12.83^{fg}	2.78	21.65
8	3.21	3.21	3.21	0.00	3.2^{h}	0	0
9	19.24	19.24	19.24	0.00	19.24^{ef}	0	0
10	14.43	20.85	17.64	1.85	17.64^{ef}	3.21	18.18
11	24.05	28.86	24.05	1.60	25.66^{de}	2.78	10.83
12 MW	8.02	16.04	11.22	2.33	11.76^{fgh}	4.04	34.32
13 MW	9.62	12.83	9.62	38.7	10.69^{fgh}	1.85	17.32
14 RW	99.42	99.42	99.42	0.00	99.42^{a}	0	0
15 RW	91.40	75.37	86.59	4.75	84.45^{a}	8.23	9.74

For a given Ca^{++} value, mean concentrations followed by the same letter are not significantly different.($p<0.05$)

7. Magnesium (Mg^{++})

Magnesium (Mg) is a common ingredient of natural water because it is very abundant in the earth's crust in the form of salts with a high solubility in water. It is the second most important component of hardness, accounting for 15-20% of overall hardness expressed as $CaCO_3$ [24]. The results shown in (Table 8) indicate that the Magnesium values range from (1.92 - 33.6 mg/1) in the treatment and purification water stations. The lowest values recorded at the station (8) with an average concentration (1.92 mg/l). This may be due to the inaccuracy and calibration of the analysis equipment in this station, which lead to a very significant decrease in the value of Magnesium. For the samples No.12 and 13 the measured Magnesium are 7.04 mg/l and 6.4 mg/l respectively. This is nearly identical to the Magnesium stated on the container's label by the manufacturer. This means the manufacturer did not include any inaccurate information on the label. The measured Magnesium for the samples No.14 and 15 ere 59.52 mg/l and 50.56mg/l respectively. This is as a result of the fact that these are the sites of home water that comes directly from groundwater, which contains a high percentage of dissolved salts, which leads to an increase in Magnesium. ANOVA and post hoc testing in (Table 8) show that there was significant differences with a statistical significance for the Magnesium with the other sites ($p<0.05$) where the value of (Sig=0.000). This indicates that there is a difference for the mean Magnesium between the fifteen sites, as a result of the difference these sites of each other in type of water source they are affected by sources of pollution. In general, the values of Magnesium recorded in this study did not exceed permissible limits for international standards of drinking water are (150 mg/l) for both WHO and LNCSM [15,16].

Table 8: Average of Magnesium (Mg^{++} mg/l) in water samples with standard deviation, standard error and coefficient variance values

No	Con 1	Con 2	Con 3	S.E	AVERAGE	SD	CV %
1	33.6	33.6	33.6	0.00	33.6^{c}	0	0
2	16.32	20.16	17.28	1.15	17.92^{d}	2.00	11.15
3	4.8	4.8	4.8	0.00	4.8^{hi}	0	0
4	14.4	14.4	16.32	0.64	15.04^{de}	1.11	7.37
5	4.8	7.68	5.76	0.85	6.08^{ghi}	1.47	24.12
6	7.68	9.6	7.68	0.64	8.32^{fgh}	1.11	13.32
7	8.64	5.76	8.64	0.96	7.68^{fgh}	1.66	21.65
8	1.92	1.92	1.92	0.00	1.92^{i}	0	0
9	11.52	11.52	11.52	0.00	11.52^{ef}	0	0
10	8.64	12.48	10.56	1.05	10.56^{efg}	1.92	18.18
11	14.4	17.28	14.4	0.96	15.36^{de}	1.66	10.83
12 MW	4.8	9.6	6.72	1.39	7.04^{fghi}	2.42	34.32
13 MW	5.76	7.68	5.76	0.64	6.4^{fghi}	1.11	17.32
14 RW	59.52	59.52	59.52	0.00	59.52^{a}	0	0
15 RW	54.72	45.12	51.84	2.84	50.56^{b}	4.93	9.74

For a given Mg^{++} value, mean concentrations followed by the same letter are not significantly different.($p<0.05$)

8. Sodium (Na^{+})

Sodium (Na) is a common element that is found in most natural waters. It is the sixth most prevalent element. Sodium can be found in a variety of minerals, the most common of which is rock salt (sodium chloride). In many parts of the world, increased pollution of surface and groundwater has resulted in a significant increase in the Na content of drinking water over the last decade [24]. Proper quantity of sodium in human body prevents many fatal diseases like kidney damages, hypertension, headache etc [22]. The results shown in (Table 9) indicate that the sodium values range from (1.92 - 14.39 mg/1) in treatment and purification water stations. The lowest values recorded at the station (8) with an average concentration (1.92 mg/l). This may be due to the inaccuracy and calibration of the analysis equipment in this station, which lead to a very significant decrease in the value of Sodium. For the samples No.12 and 13 the measured Sodium are 3.93 mg/l and 10.10 mg/l respectively. This is nearly identical to the sodium stated on the container's label by the manufacturer. This means the manufacturer did not include any inaccurate information on the label. The measured sodium for the samples No.14 and 15 are 23.24 mg/l and 18.95 mg/l respectively. This is as a result of the fact that these are the sites of home water that comes directly from groundwater, which contains a high percentage of dissolved salts, which leads to an increase in sodium. ANOVA and post hoc testing in (Table 9) show that there were significant differences with a statistical significance for the Sodium with the other sites ($p<0.05$) where the value of (Sig=0.000). This indicates that there is a difference for the mean sodium between the fifteen sites, as a result of the difference these sites of each other in kind of water source they are affected by sources of pollution. In general, the values of Sodium recorded in this study did not exceed permissible limits for international standards of drinking water are (200 mg/l) for both WHO and LNCSM [15,16].

Table 9: Average of Sodium (Na+ mg/l) in water samples with

standard deviation, standard error and coefficient variance values

No	Con1	Con 2	Con3	S.E	AVERAGE	SD	CV%
1	14.39	14.39	14.39	0.00	14.39^{c}	10.18	70.71
2	9.96	10.37	10.37	0.13	10.23^{d}	0.28	2.78
3	3.93	3.93	3.923	0	3.93^{j}	0	0
4	7.550	7.550	7.550	0	7.55^{g}	0	0
5	5.14	5.14	5.54	0.134	5.27^{i}	0.28	5.40
6	8.35	8.35	8.35	0	8.35^{f}	0	0
7	6.34	6.34	6.34	0.00	6.34^{h}	0	0
8	1.92	1.92	1.92	0.00	1.92^{k}	0	0
9	5.14	5.14	5.54	0.134	5.27^{i}	0.28	5.40
10	8.35	8.35	8.35	0.00	8.35^{f}	0	0
11	9.16	9.56	9.56	0.134	9.43^{e}	0.28	3.02
12MW	3.93	3.93	3.93	0.00	3.93^{j}	0	0
13MW	9.96	9.96	10.37	0.134	10.10^{d}	0.28	2.82
14 RW	23.24	23.24	23.24	0.00	23.24^{a}	0	0
15 RW	19.22	18.82	18.82	0.134	18.95^{b}	0.28	1.50

For a given Na^{+} value, mean concentrations followed by the same letter are not significantly different.($p<0.05$)

9. Potassium (K^{+})

Potassium is found in all human and animal tissues, notably in plant cells, because it is required for the proper functioning of living organisms [22]. Although potassium (K) is a plentiful element, it rarely exceeds 20 mg/L in natural freshwater [24]. The results shown in (Table 10) indicate that the potassium values range from (0.03 - 0.87 mg/l) in treatment and purfication water stations. The lowest values recorded at the station (8) with an average concentration (0.03 mg/l). This may be due to the inaccuracy and calibration of the analysis equipment in this station, which lead to a very significant decrease in the value of Potassium. For the samples No.12 and 13, the measured sodium are 0.03 mg/l and 0.034 mg/l respectively. This is nearly identical to the potassium stated on the container's label by the manufacturer. This means the manufacturer did not include any inaccurate information on the label. The measured sodium for the samples No.14 and 15 are 1.95 mg/l and 0.85 mg/l respectively. This is as a result of the fact that these are the sites of home water that comes directly from groundwater, which contains a high percentage of dissolved salts, which leads to an increase in Potassium. ANOVA and post hoc testing in (Table 10) show that there was significant differences with a statistical significance for the Potassium with the other sites ($p<0.05$) where the value of (Sig=0.000). This indicates that there is a difference for the mean Potassium between the fifteen sites, as a result of the difference these sites of each other in kind of water source they are affected by sources of pollution. In general, the values of Sodium recorded in this study did not exceed permissible limits for international standards of drinking water for each of the WHO (20 mg/l) [15] and LNCSM (40 mg/l) [16].

Table 10: Average of Potassium (K^{+} mg/l) in water samples with standard deviation, standard error and coefficient variance values

No	Con 1	Con 2	Con 3	S.E	AVERAGE	SD	CV %
1	0.87	0.87	0.87	0.00	0.87^{c}	0	0
2	0.95	0.95	0.95	0.00	0.95^{b}	0	0
3	0.11	0.11	0.11	0.00	0.11^{i}	0	0
4	0.41	0.41	0.41	0.00	0.41^{e}	0	0
5	0.18	0.18	0.18	0.00	0.18^{h}	0	0
6	0.26	0.26	0.26	0.00	0.26^{g}	0	0
7	0.26	0.34	0.26	0.03	0.28^{g}	0.04	15.54
8	0.03	0.03	0.03	0.00	0.03^{j}	0	0
9	0.11	0.11	0.11	0.00	0.11^{i}	0	0
10	0.34	0.34	0.34	0.00	0.34^{f}	0	0
11	0.34	0.34	0.34	0.00	0.34^{f}	0	0
12 MW	0.03	0.03	0.03	0.00	0.03^{j}	0	0
13 MW	0.34	0.34	0.34	0.00	0.34^{f}	0	0
14 RW	1.95	1.95	1.95	0.00	1.95^{a}	0	0
15 RW	0.80	0.87	0.87	0.02	0.85^{d}	0.04	5.23

For a given K^{+} value, mean concentrations followed by the same letter are not significantly different.($p<0.05$)

10. Chloride (Cl^{-})

Chloride anions (Cl^{-}) are commonly found in natural waterways. Water that has come into touch with Cl-containing geological formations has a high Cl^{-} content. Otherwise, a high Cl^{-} level could indicate sewage or industrial waste pollution, as well as the entry of seawater or salty water into a freshwater body or aquifer. A salty taste in water dependents on the ions with which the Cl^{-} are associated. With Na ions the taste is detectable at about 250 mg/L, but with Ca or Mg the taste may be undetectable at 1,000 mg/L. Chlorides being highly soluble is present in all waters but the amount is often very low in natural waters [24]. The results shown in (Table 11) indicate that the chloride values range from (10.64 - 27.19 mg/l) in treatment and purification water stations. The lowest values recorded at the station (8) with an average concentration (10.64 mg/l). This may be due to the inaccuracy and calibration of the analysis equipment in this station, which lead to a very significant decrease in the value of chloride. The measured chloride for samples No.12 and 13 are 13 mg/l and 28.37 mg/l respectively. This is nearly identical to the chloride stated on the container's label by the manufacturer. This means the manufacturer did not include any inaccurate information on the label. The measured chloride for the samples No.14 and 15 are 55.55 mg/l and 40.19 mg/l respectively. This is as a result of the fact that these are the sites of home water that comes directly from groundwater, which contains a high percentage of dissolved salts, which leads to an increase in chloride. ANOVA and post hoc testing in (Table 11) show that there were significant differences with a statistical significance for the chloride with the other sites ($p<0.05$) where the value of (Sig=0.000). This indicates that there is a difference for the mean chloride between the fifteen sites, as a result of the difference these sites of each other in kind of water source they are affected by sources of pollution. In general, the values of chloride recorded in this study did not exceed permissible limits for international standards of drinking water are (250 mg/l) for both WHO and LNCSM [15,16].

Table 11: Average of Chloride (Cl^- mg/l) in water samples with standard deviation, standard error and coefficient variance values

No	Con1	Con 2	Con 3	S.E	AVERAGE	SD	CV %
1	28.37	24.82	28.37	0.033	27.19^{c}	2.05	7.53
2	17.73	21.28	14.18	0.058	17.73^{de}	3.55	20
3	10.64	14.18	10.64	0.033	11.82^{e}	2.05	17.32
4	10.64	17.73	14.18	0.058	14.184^{e}	3.55	25
5	14.18	17.73	14.18	0.033	15.36^{de}	2.05	13.32
6	10.64	10.64	14.18	0.033	11.82^{e}	2.05	17.32
7	17.73	17.73	14.18	0.033	16.55^{de}	2.05	12.37
8	14.18	10.64	7.09	0.058	10.64^{e}	3.55	33.33
9	10.64	7.09	10.64	0.033	9.46^{e}	2.05	21.65
10	17.73	10.64	14.184	0.058	14.18^{e}	3.55	25
11	24.82	24.82	21.28	0.033	23.64^{cd}	2.05	8.66
12MW	14.18	14.18	10.64	0.033	13.00^{e}	2.05	15.75
13MW	24.82	35.46	24.82	0.100	28.37^{c}	6.14	21.65
14 RW	53.19	60.28	53.19	0.07	55.55^{a}	4.09	7.37
15 RW	39.01	39.01	42.55	0.033	40.19^{b}	2.05	5.09

For a given Cl^- value, mean concentrations followed by the same letter are not significantly different.($p<0.05$)

11. Nitrate NO_3^-

The majority of nitrate present in natural streams comes from organic and inorganic sources, with the former encompassing waste discharges and the latter comprising chiefly consisting of manmade fertilizers. However, both bacterial oxidation and plant nitrogen fixation can yield nitrate. Nitrate concentrations are of particular interest for a variety of reasons. Most significantly, high nitrate levels in drinking water endanger infants by causing the "blue baby" syndrome (methaemoglobinaemia) [23]. The results in (Table 12) in the current study indicate that the nitrate values range from (6.17 - 12.17 mg/l) in treatment and purification water stations. The lowest values recorded at the station (5) with an average concentration (6.17 mg/l) and the highest values recorded at the station (11) with an average concentration of (12.17 mg/l) . This may be due to the inaccuracy and calibration of the analysis equipment in this station, which lead to a very significant decrease in the value of nitrate. For the samples No.12 and 13, the measured nitrate are 8.42 mg/l and 6.42 mg/l respectively. This is nearly identical to the nitrate stated on the container's label by the manufacturer. This means the manufacturer did not include any inaccurate information on the label. The measured nitrate for the samples No.14 and 15 are 7.17 mg/l and 7.25 mg/l respectively. This is as a result of the fact that these are the sites of home water that comes directly from groundwater, which contains a high percentage of dissolved salts, which leads to an increase in nitrate. ANOVA and post hoc testing in (Table 12) show that there were significant differences with a statistical significance for the nitrate with the other sites ($p<0.05$) where the value of (Sig=0.000). This indicates that there is a difference for the mean nitrate between the fifteen sites, as a result of the difference these sites of each other in type of water source they are affected by sources of pollution. In general, the values of nitrate recorded in this study did not exceed permissible limits for international standards of drinking water for each of the WHO (50 mg/l) [15] and LNCSM (45 mg/l) [16] (Table 13).

Table 12: Average of Nitrate (NO_3^- mg/l) in water samples with standard deviation, standard error and coefficient variance values

No	Con 1	Con 2	Con 3	S.E	AVERAGE	SD	CV %
1	10.75	10	10.5	0.22	10.42^{b}	0.18	1.70
2	8	8	7.25	0.25	7.75^{cd}	0.53	6.84
3	7.5	8	7.25	0.22	7.58^{d}	0.18	2.33
4	8.5	8.5	8.5	0.00	8.5^{c}	0	0
5	6	6.5	6	0.17	6.17^{h}	0	0
6	7	7.25	7	0.08	7.08^{defg}	0	0
7	6.75	6.75	6.75	0.00	6.75^{efgh}	0	0
8	10.5	10.25	10.25	0.08	10.33^{b}	0.18	1.71
9	6.25	6.5	6.25	0.08	6.33^{gh}	0	0
10	6.75	7	6.25	0.22	6.67^{efgh}	0.35	5.30
11	11.75	12.5	12.25	0.22	12.17^{a}	0.35	2.91
12MW	8.5	8.25	8.5	0.08	8.42^{c}	0	0
13MW	6.25	6.5	6.5	0.08	6.42^{fgh}	0.18	2.75
14RW	7	7.25	7.25	0.08	7.17^{def}	0.18	2.47
15RW	7.5	7	7.25	0.14	7.25^{de}	0.18	2.44

For a given NO_3^- value, mean concentrations followed by the same letter are not significantly different.($p<0.05$)

The (Table 13) shows a summary of the results (ranges) obtained from this study compared to international standards of drinking water for each of the World Health Organization (WHO) and the Libyan National Centre for Standardization and Metrology (LNCSM).

Table 13: The safe limits of WHO and LNCSM for determining drinking water quality.

Parameter	WHO permissible limits	LNCSM permissible limit	Current Study
pH	6.5-8.5	6.5-8.5	5.99 - 7.48
Electric conductivity (µS/cm)	2300	2300	10.03 - 590
Total dissolved solids (mg/l)	1000	1000	5 - 283.33
Alkalinity(mg/l)	200	-	44.73-390.4
Total hardness (mg/l)	500	500	8.01-248.20
Ca^{++}(mg/l)	200	-	3.2-99.42
Mg^{++} (mg/l)	150	150	1.92-59.52
Na^{+} (mg/l)	200	200	1.92-18.95
K^{+} (mg/l)	20	40	0.03-1.95
Cl^{-} (mg/l)	250	250	9.46-55.55
NO$_3^{-}$ (mg/l)	50	45	6.75-7.25

Conclusion

The studied water samples in different water treatment and purification stations systems revealed that almost all of the physical and chemical parameters are in good status, expressing their suitability for drinking purposes. Major problems in sample No. 8 that were low in most chemical and physical parameters. This may be due to the impact of pollution from the source at this station or because of the inaccuracy of the devices used in water purification. Also, there is a problem in samples No. 14 and 15 (residential water) that were high in some physical and chemical parameters, especially in Electric Conductivity (EC) (590 µS/cm), Total Dissolving Salts (TDS) (288.33 mg/l), Alkalinity (390.4 mg/l) and Total Hardness (248.20 mg/l). Poor maintenance of the water source is the likely reason for high concentration in these parameters or may be due to the geological nature of the water source. To ensure public health, competent authorities should closely monitor the quality of drinking water supplied to consumers.

Conflict of interest

The authors declare no conflicts of interest regarding the publication of this work.

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