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Original article

Estimate the Contents and Types of Water Well Salts by the Palmer Roger Model Affecting the Corrosion of Al-Bayda City (Libya) Network Pipes

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Abstract
Corrosion in drinking water distribution networks is a significant issue that impacts infrastructure longevity, water quality, and the environment. This study focuses on the environmental impact of corrosion in the water distribution networks of Al-Bayda city, Libya. This research aims to measure the impact of drinking water quality on the corrosion of distribution pipes. The study analyzed ten water samples collected from different wells in Al-Bayda. explanation of water quality parameters, such as pH, electrical conductivity (EC), total dissolved solids (TDS), chloride, sulfate, bicarbonate, calcium, magnesium, sodium, and potassium, were measured. The results indicated that calcium bicarbonate ($Ca(HCO_3)_2$) was the dominant mineral in most samples, comprising 45% to 59% of the total salts, while sodium chloride (NaCl) was predominant in one sample, making up 56%. The study concludes that the groundwater in Al-Bayda has a significant potential to cause corrosion in the distribution network, primarily due to its chemical composition and low saturation levels of calcium carbonate. Recommendations include regular monitoring of water quality, the use of corrosion-resistant materials, water treatment to reduce corrosive agents, and infrastructure upgrades to mitigate the impact of corrosion.

Keywords. Water, Salts, Network, Pipes**.**

Introduction

The Corrosion monitoring using the coupon tests can help to optimize drinking water quality parameters, and it can also help to plan reconstructions of pipes used for drinking water delivery. Corrosion negatively influences the quality of distributed water in many parameters. For example, colour, turbidity, conductivity, and iron concentration increase, and the content of dissolved oxygen and active chlorine decreases. In cast iron and steel pipes. The most common indicators of corrosion in the distribution system are red water complaints and leaks. Corrosion of iron is also the primary factor controlling biofilm growth [1]. Corrosiveness of particular water depends on its chemical properties (e.g., pH, alkalinity, dissolved oxygen content, dissolved solids, etc) and physical characteristics (temperature, flow, velocity), as well as the nature of the pipe material.

In addition to general corrosion, localized pitting corrosion may also occur if there are imperfections in the metal, oxide film or scale. Pitting is accelerated by high levels of chloride and sulfate. Microorganisms can also promote corrosion by creating areas with different concentrations of oxygen, minerals, and metals. Some microorganisms also catalyze reactions associated with the corrosion process. Corrosion products of iron pipe provide habitats for microbial growth and react with disinfectant residuals, preventing the disinfectant from penetrating the biofilm [2]. Corrosion scales formed by the accumulation of corrosion products could serve as the breeding ground for microbes and sinks for heavy metals or other contaminants (e.g., arsenic, vanadium, lead).[3]

Corrosion and scaling may cause pipe blocking. As a result, it may reduce the flow and create some other problems in the pipelines. It can also damage the pipeline. If it occurs, water leakage increases, and so water loss will be high [4]. Calcium carbonate is probably the most common type of scale found in cooling water systems; it forms an extremely tenacious heat-insulating deposit. Calcium and bicarbonate alkalinity are found in almost all cooling waters. The addition of heat, or a sharp rise in pH, will cause calcium bicarbonate to decompose and form carbon dioxide and calcium carbonate [5]. This study aims to measure the impact of the environment of drinking water in pipe distribution networks at Al-Bayda city, by calculating and determining the following points: determining the chemical and physical parameters of water samples collected from some wells as E.C, T.D.S, and pH. Determine the contents of Na^+, K^+, Ca^{+2} and $Mg^{+2.}$ Estimate the concentration of Cl^-, HCO_3^-, SO_4^{-2}, then use some models as the Palmer-Roger, to estimate the salt composition of water samples.

Methods

Area of study

The city of Al-Bayda is located in the northeast of Libya, at the top of the Green Mountain, at a latitude of 21.44° N intersects with a longitude 32.76° E. It is considered one of the best Libyan cities in terms of nature

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and climate, as its climate is mild and tends to be cool in winter, Location of Al Bayda, Libya As shown in the figures (1&2).

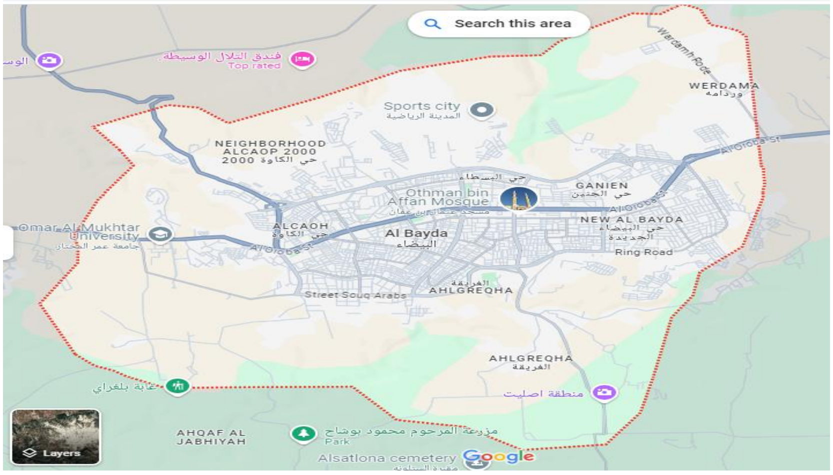

Figure 1. The internal layout of Al-Bayda city

Figure 2. Location of Al Bayda, Libya.

Sampling

Ten water samples of drinking water sources were collected from 10 ground wells at Al Bayda city were randomly selected as given in Table (1).The samples were stored in polyethylene bottles in frozen then transferred to the laboratory.

Table 1. The Wells Location, No. of Samples

No. of Sample	No. of wells from which the sample was take
1	3690/4/C - G109
2	3690/1/A - G141
3	3690/4/C - G131
4	3690/4/C - G133
5	3690/1/A - G82
6	3690/1/A - G 128
7	3690/4/C - G 69
8	3690/4/C - G 246
9	3690/3/I - G 322
10	3690/1/A - G192

Methods of water analysis

All the methods used in this study were according to standard methods, and all the samples were analyzed in Omar Al Mukhtar University, the Central Lab of Chemical Analysis.

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pH

The pH values were measured by a digital pH (Type pH meter Model in lab pH 720 made in Germany). The pH of the water samples was measured directly at locations. The device was calibrated and adjusted using Buffer solutions of (4, 7 and 9). The device electrode was cleaned and thoroughly washed with distilled water after calibration and after each measurement. The A device for measuring pH, total dissolved solids (TDS), and electrical conductivity.

Electrical conductivity

Electrical conductivity is measured in the laboratory of Chemical Department using a device conductivity (Type conductivity meter Model in lab cond720¸ made in Germany). In measuring the electrical conductivity, this device has been calibrated and controlled using a standard potassium chloride solution. When measuring TDS, the device reads directly the unit (mg/L) after washing and cleaning the device pole with distilled water and then washing with water of the sample to measure the dissolving salts and repeat these steps when replacing a sample with another sample.

Total Alkalinity

The alkalinity was measured by titration with hydrochloric acid (HCl). The methyl orange indicator was used [6].

Chloride

The chloride was estimated by Mohr by titration with silver nitrate ($AgNO_3$) and using K_2CrO_4 solution as an indicator [6].

Calcium and Magnesium

Calcium (Ca^{+2}) was estimated by titration with EDTA (0.01 M) using Murexide as an indicator. For magnesium (Mg^{+2}), it was calculated by the difference between total calcium carbonate ($CaCO_3$) and calcium (APHA).

Sulphate

Sulfate concentration (SO_4^{-2}) was measured at the Al-Bayda laboratory, where the absorbance was measured at 450 nm, using a light absorption device from a kind of Spectral Photometer DR2800 (HACH), using the detector (Sulfa Ver 4 Reagen). Follow the operating methods described in the operating manual of the device (Hach Company, 2007, All rights reserved. Printed in Germany). Denotes USEPA accepted or approved for water or wastewater analysis.

Sodium and potassium

The concentration of sodium and potassium was determined at the Central Laboratory of Chemistry Studies of the Faculty of Science at the University of Omar Al-Mukhtar-Al-Bayda, using the JENWAY-CLINICAL PFP7.13.6.

Results

Water parameters analysis

The values of the parameters can be described as follows:

Temperature water values

It is one of the most important factors in the chemical and physical studies that affect most of the biological and chemical processes occurring in natural water bodies. In this study, the values of water temperature ranged 24.1 to 25.2 C^0 for all the water samples collected from the wells (Table 2).

pH Values

The pH value is the master control parameter in the environment for chemical and biological systems of water. The carbonate cycle, composed of CO_2, H_2CO_3, $HCO_3^{-1,}$ and CO_3^{-2}, plays a role for regulating pH [7]. The main factors controlling the variation of pH in any environment are: dissolved oxygen, water temperature, land runoff, decomposition of organic matter, photosynthetic activity, respiration of aquatic organisms, and some physico-chemical processes, such as precipitation and oxidation-reduction taking place in the environment.

In this study the values of pH for studied water samples were fluctuated in the range of (7.02 – 7.34), the low value of pH was recorded in the sample 7, The remaining of the studied water samples recorded the value of pH between (7.18 – 7.3) the high value of pH was value recorded in the sample 4. According to the guidelines of WHO [8], the recommended value of pH for drinking water lies between 6.5- 8.5. Also, the increasing pH values lead to an increase in the rate of corrosion.

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Total Dissolving Salts (TDS)

Total dissolved salts are the definite property of water, which distinguishes it from natural waters [9] and is defined as the total weight of salts in mille grams in one thousand grams per milliliter of water. It is affected by several factors such as the rates of renewing, sewage, and precipitation, besides the physical and climatic conditions [7]. The drinking water is almost ranging between (500 -1000 mg/ l). The TDS waters of the water is highly variable, depending mainly upon ionic influences of drainage, exchange from the surrounding land, atmospheric sources, equilibrium, and exchange with sediments inside the water body. The TDS values recorded in this study for water samples are in harmony with those values recorded by W H O, The T.D.S. values depend on the types of cations and anions, besides the pH values of the water samples, also some factors of the sample locations and soil types may be affecting the contents of T.D.S. When TDS values range between 350-500 ppm, they fall within internationally accepted limits. They are safe to drink, but they may have a mild taste due to dissolved minerals such as calcium and magnesium. These values contain aggressive ions, such as chloride, that can increase the risk of corrosion of pipes [1-3].

Electrical Conductivity (E.C)

The most important test to determine the total absorption of soluble salts is the conductivity test, as water's conductivity depends mainly on the dissolved salts. There is a linear relationship between increased salt concentration and higher conductivity [8]. Salts are more soluble in groundwater than in surface water. In this study, the values ranged between (low 583-900 µS/cm) for water samples collected from the wells. the values of the remaining samples range between (611-800 µS/cm). The E.C. values are following the T.D.S. values. According to the guidelines of drinking water, which are stated by the WHO, the E.C value is below 2000 µS/Cm, the present E.C values which were recorded in this study, are lower than this value. geochemistry of the area around the wells, as shown in Table 2.

Table 2. The pH, E.C and TDS values of the studied water sample

No. of Sample	pH	E.C (µs/cm)	TDS (mg/l)
1	7.26	800	480
2	7.18	733	386
3	7.22	900	500
4	7.34	677	400
5	7.27	611	428
6	7.27	583	350
7	7.02	750	375
8	7.3	640	364
9	7.23	689	450
10	7.3	642	385

Chloride

If its concentration reaches 1000 ppm, the water becomes unfit to drink, and the permitted limit is about 250 ppm [6]. The low value of chloride was recorded in the sample 6 (40mg/L). The high value of chloride was recorded in the sample 9 (200 mg/L). The values chloride ions of the remaining samples range between (50 – 79 mg/L). According to the guide line of WHO, the recommended value of chloride for drinking water is lie between (200 -250 mg/l). Table 3 shown the contents of chloride in the water samples of the studied area in mg/l.

Table 3. The contents of chloride in the water samples of the studied area in mg/ L:

No. of Sample	Chloride (mg/l)
1	60
2	74
3	79
4	55
5	78
6	40
7	68
8	50
9	200
10	54

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Sulphate SO_4^{-2}

Sulfates reach the water from the solubility of certain minerals such as calcium sulphate or the melting of carbon dioxide in the air and the concentration of sulphates in the water ranges from 5 to 200 parts per million and the maximum permissible limit is 250 parts per million and gives a bitter taste of water if exceeded [9]. In the current study, the low value of sulphate was recorded in sample 10 (19mg/L). The high value of sulphate was recorded in sample 1 (76 mg/L), the values of sulphate ions of the remaining samples range between 21-70 mg/L. As shown in Table 4.

Table 4. The contents of sulfate SO_4^{-2} in the water samples of the studied area (mg/ L)

No. of Sample	SO_4^{-2} (mg/l)
1	76
2	56
3	48
4	70
5	43
6	21
7	36
8	38
9	50
10	19

Alkalinity (Bicarbonate)

The bicarbonate ions are one of the most abundant ions which present in drinking water, also it is give the water its alkalinity value. Most of the groundwater contains high values of bicarbonate ions compared with carbonate, which also depends on the geochemistry of the regions of water sampling [10]. In this study, the bicarbonate alkalinity values of the collected water samples are reported in Tables 4&5. The low value was recorded for the water sample 6 (18.4 mg /L). The high value was recorded for the water sample 10 (220 mg / L). The levels for the remaining samples of bicarbonate concentrations fluctuated in the range of (195.6 - 216.15 mg/L). Table (5). Total alkalinity and bicarbonate values are used in the calculations of the corrosive indexes. The decomposition of bicarbonate to carbonate affects the pH, which directly affects the precipitate of some salts on the water pipes. Also, the total alkalinity depends on the total amounts of other ions as hydroxide (OH^-). In this study, the most common type of alkalinity is Bicarbonate [7-8].

Table 5. Contents of Bicarbonate Alkalinity in the water samples of the studied area in mg/ L:

No. of Sample	(HCO^{-3}) mg /l
1	216.15
2	209.2
3	198.3
4	202.5
5	210.7
6	180.4
7	195.6
8	200.6
9	210.45
10	220.3

Calcium and Magnesium (Ca^{+2} & Mg^{+2})

Magnesium and calcium are the most abundant ions present in drinking water. Calcite and dolomite ($CaCO_3$ and $CaMg(CO_3)_2$) are the most common ores in the area under study; this may explain the presence the high values of calcium. The presence of calcium in water samples is one of the most significant problems to pipes corrosion, at high pH values, the $CaCO_3$ precipitates in the pipes.

Calcium

According to the listed recommendations of W.H.O for the maximum acceptable levels of calcium in drinking water (125 mg/L). WHO does not set a strict maximum limit for calcium in drinking water, as these levels are not harmful. When water analysis was set up, the calcium concentrations fluctuated in the range of 56 – 80 mg/L. Calcium concentrations in the range of 56-80 mg/L are considered safe and suitable for drinking water (Table 6).

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Magnesium

The magnesium concentration levels in the collected water samples range from 9 – 20 mg/L (Table 6). Some of the water samples exhibit low concentration levels of magnesium, and they are below the listed recommendation of WHO (50 mg/L).

Table 6. The contents of calcium (Ca^{+2}) and magnesium (Mg^{+2}) in the studied water samples.

No. of Sample	**Calcium**	**Magnesium**
1	78	13
2	70	13
3	80	20
4	56	20
5	80	15
6	76	17
7	79	9
8	64	19
9	59	14
10	60	12

Sodium and Potassium (Na^+ & K^+

The most common salts of sodium and potassium in drinking water are sodium chloride and potassium chloride (NaCl and KCl). Many factors are affecting the distribution of the water samples.

Sodium

The concentrations of sodium are displayed in Table 7. The data obtained shows that sodium concentration values are considerably lower than the listed recommendation of WHO (200 mg/L). The range of sodium concentration values in the samples is between 12 - 75 mg/l**.**

Potassium

The values of potassium concentrations in the collected samples are reported in Table 7. Potassium levels range from 2 – 6 mg/L. The EEC recommended 10 mg/L as a guideline. Therefore, the potassium levels of collected samples are considered safe for human health.

Table 7. The contents of Sodium (Na^+) and potassium (K^+) hardness in the water samples of the city of Al-Bayda in mg/ L:

No. of Sample	Potassium	Sodium
1	2	20
2	6	18
3	4	12
4	4	18
5	6	22
6	3	12
7	2	23
8	2	26
9	2	75
10	5	22

The chemical structure of the salt types of the studied water samples

Palmer Roger model

To estimate the types of salts which mainly found in the water sample, the Palmer-Roger model. This model is used in this study to identify groundwater quality and chemical composition. The type and percentages of salts found in water can be identified by expressing the concentration of all major ions in the percentage of total equivalents. This model is a vertical plan component of three columns. This model is applied by placing anions (Cl^-, $SO_4^{-2,}$ and HCO^-) and the cations of (K^+, Na^+, $Mg^{+2,}$ and Ca^{+2}) are placed on the third column. By matching the first and third columns, the type and percentage of salts in the water sample are determined in the middle column [8 -9].

By the application of this model on the studied groundwater samples of the studied area, the chemical composition and groundwater quality shown in figures 3–12 were identified. The results showed that there are differences in the chemical structure. The calculations for the percentage of all types of salts contained in the chemical composition of each sample shown in figures of (3-12) showed that calcium bicarbonate Ca

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(HCO_3) is the predominant mineral in water samples No of: (1-8,10) and a percentage ranging from 45-59%, and Sodium chloride NaCl is the predominant mineral in water samples No: (9) and a percentage ranging from 56 %.

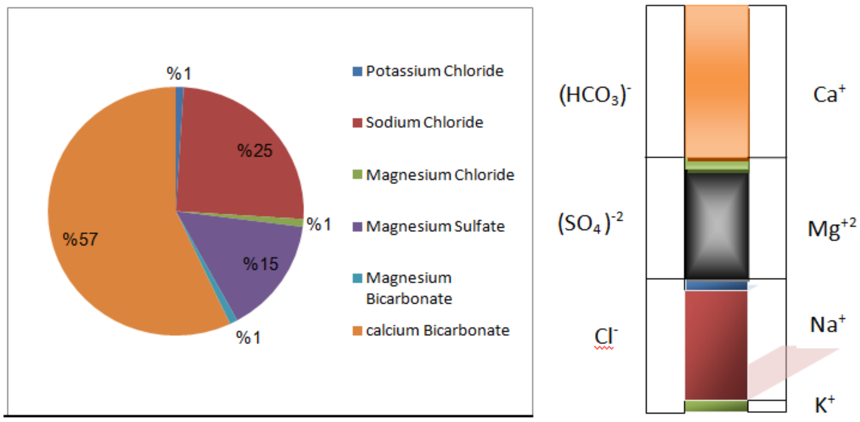

Figure 3. The percentage of salt distribution of Sample 1

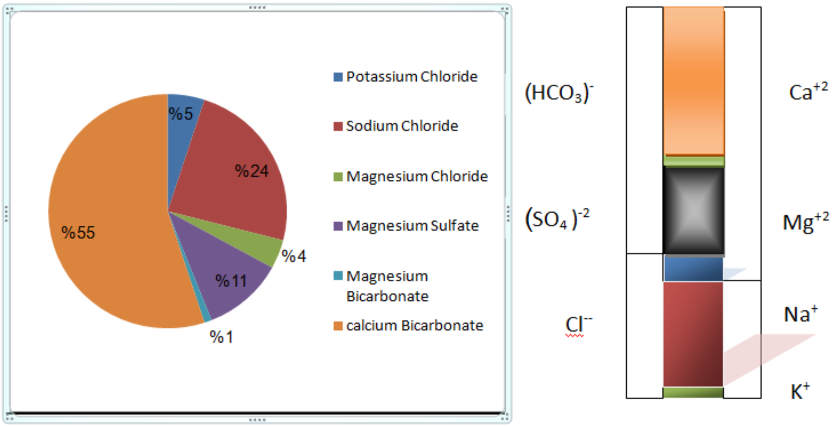

Figure 4. The percentage of salt distribution of Sample 2

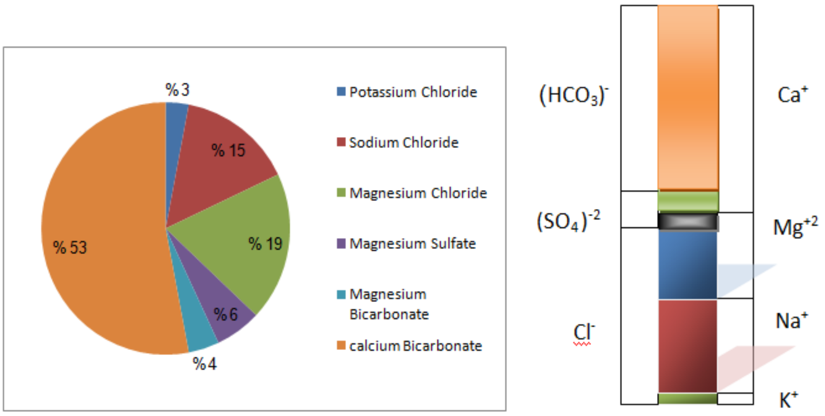

Figure 5. The percentage of salt distribution of Sample 3

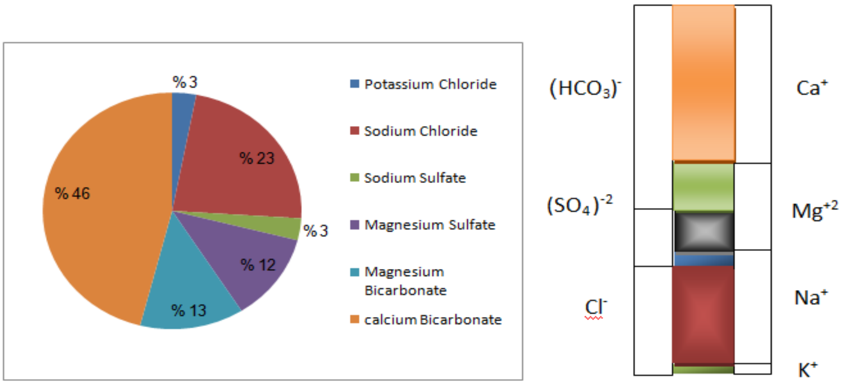

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Figure 6. The percentage of salt distribution of Sample 4

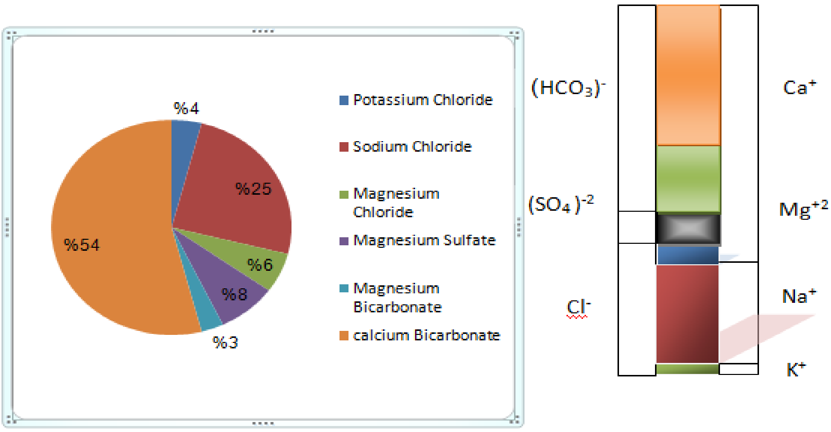

Figure 7. The percentage of salt distribution of Sample 5

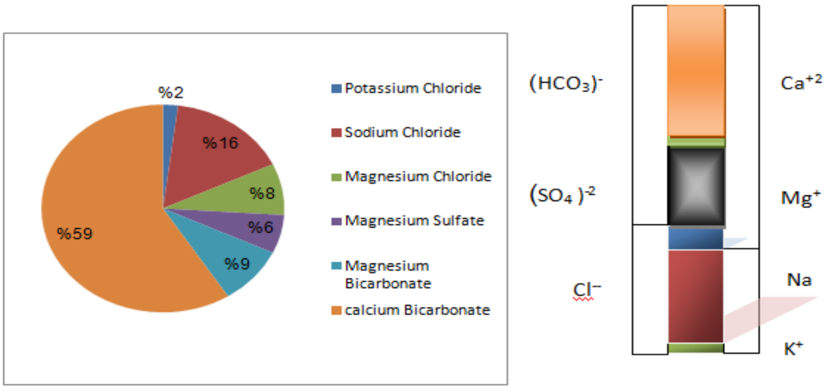

Figure 8. The percentage of salt distribution of Sample 6

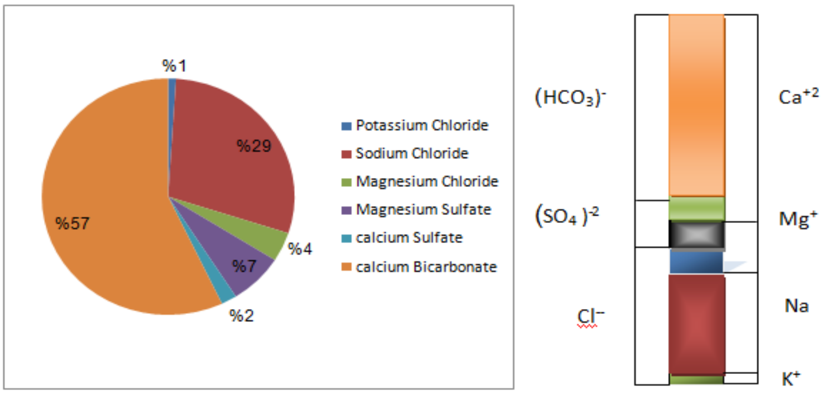

Figure 9. The percentage of salt distribution of Sample 7

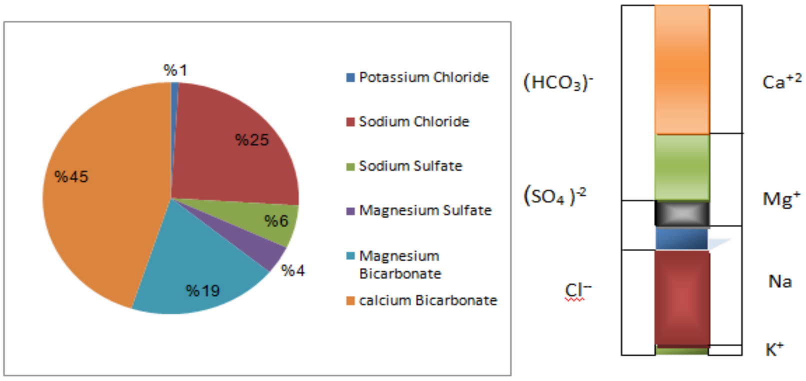

Figure 10. The percentage of salt distribution of Sample 8

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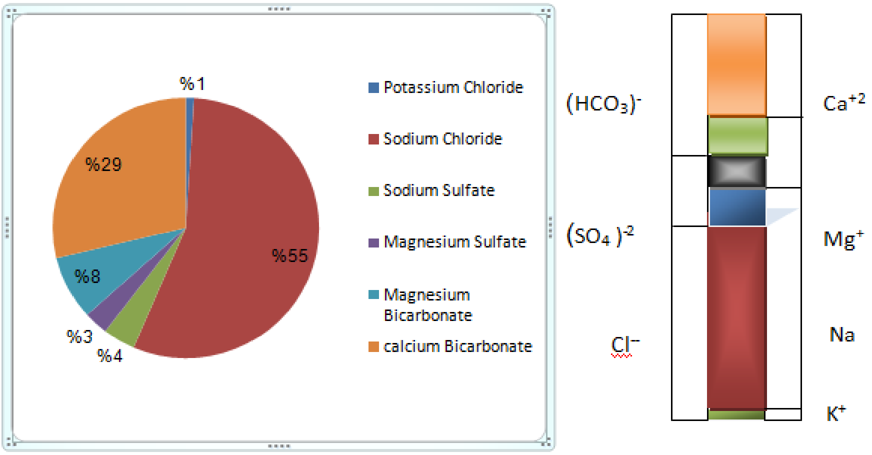

Figure 11. The percentage of salt distribution of Sample 9

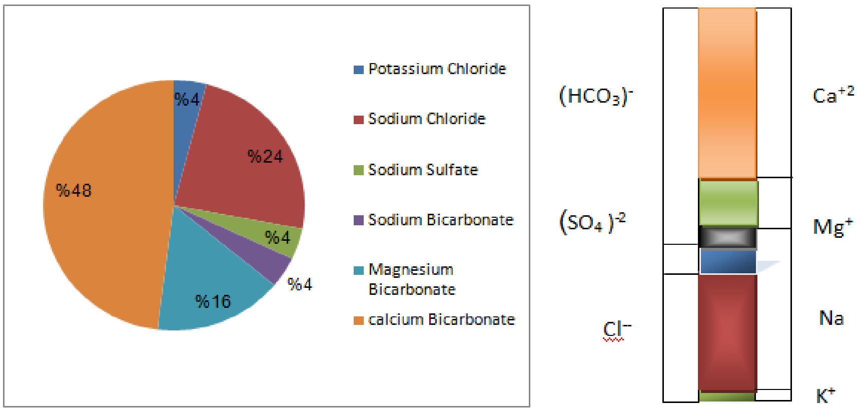

Figure 12. The percentage of salt distribution of Sample 10

Discussion

The study analyzed the types of chemical salts and estimated the chemical composition of water to assess the effect of water type in Al-Bayda on distribution networks. Groundwater quality and chemical composition were analyzed, with variations noted across samples. Internal corrosion of water distribution systems gives rise to many problems for water utilities. The first is the failure of the distribution system pipes, which often results in water leakage. The problem is also the loss of hydraulic capacity caused by a buildup of corrosion products. Corrosion negatively influences the quality of distributed water in the networks at Al-Bayda city. This study aims to measure the impact of the environment of drinking water on the pipes of distribution networks at Al-Bayda city. The Key findings: Calcium bicarbonate ($Ca(HCO_3)_2$) was the dominant mineral in most samples, comprising 45% to 59%. Sodium chloride (NaCl) was the dominant mineral in one sample, making up 56%. The type and chemical composition of water salts depended upon different factors as the type of soils, geology of the area under investigation, beside the sources of pollution near locations of water samples, according to the primary research no published studies were recorded on most networks of Libyan cities, but this problem of water salt structure and its treatment was taken places in many studies [10-19].

Conclusion

According to the results obtained in this study, the water samples containing different types of chemical salts as CaCl2, MgCl2, and NaCl, these salts may have the water corrosive impact on the water network of Albayda City.

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الملخص

تتأثر بعض انابيب شبكات توزيع المياه بسبب وجود انواع مختلفة من الاملاح التي تؤدي الي اتلافها وتأكلها ، وغالبا ما يعتمد ذلك على التركيب الملحي للمياه او نوع البيئة بشكل المحيطة بشبكة المياه وخاصة نوع التربة وبعض الخصائص الكيميائية والفيزيائية لها. هذه الدراسة تركز على نوعية التركيب الملحي للمياه على انابيب شبكة توزيع المياه بمدينه البيضاء بليبيا. حيث تم تجميع عينات مياه من عدد ابار جوفية بمدينه البيضاء ولك لتقدير نسبة الاملاح الذائبة الكلية وقيم التوصيلية الكهربائية وتراكيز كلا من الكبريتات والكلوريات والبيكربونات وكذلك تراكيز المعادن (الكالسيوم والماغنيسيوم والصوديوم والبوتاسيوم). كما تم استخدام نموذج بالمر روجر للتعرف على التركيب الملحي للمياه. وقد بينت نتائج الدراسة ان معظم الاملاح السائدة كانت على صورة بيكربونات الكالسيوم وبنسبه تراوحت ما بين (45 % - 59 %) ، مع وجود كميات مختلفة من املاح كلوريد الصوديوم، وقد خلصت نتائج الدراسة الي ان المياه الجوفية لمدينه البيضاء لبعض الابار لها خصائص تأكليه على شبكات توزيع المياه.

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