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EVALUATION OF BROMINE, MINERALS AND SOLIDS MATERIALS IN OZONE-OXIDIZED AQUEOUS SOLUTIONS

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Abstract

In this study, was evaluated the effectiveness of ozone in oxidation of metals and oxidation of organic matter was evaluated in aqueous solutions. The properties of nine samples of the most traded local bottled water in the local markets in Baghdad city were studied for three different months. This research was conducted to determine the suitability of water for drinking and it was found through laboratory tests conducted on the wide samples that some samples contain results within the permissible limit and others contain results outside the permissible limit specified by the World Health Organization and the Iraqi Ministry of Health. Acidity function and electrical conductivity for nine samples during the three months (February, April and August) came within the permissible and the samples from (1 to 9) It came within the permissible limits for turbidity which is (5NTU). The total hardness for samples (3,4,7,8,9) higher than the standards set by the Iraqi government, which is (176 mg/l). The laboratory tests of the samples proved that they contain dissolved solids within normal limits, which are (150-500 mg/l). samples (3, 4, 7, 8 and 9) have a significant increase in the calcium ion and all samples contained normal percentages of potassium and bromine, except for (sample 9). The nine samples came within the acceptable limits for fluoride.

Keywords: conductivity, fluoride, turbidity, ozone, oxidized

1-Introduction

Water treatment with an ozone generator not only kills biological microorganisms but also removes metals present in the water, such as iron, sulfur and manganese in black particles, which aid in the water filtration process [1]. For many years, ozone water treatment technology has been commercialized in municipal wastewater treatment plants and commercially as a powerful non-chemical disinfectant. Ozone has been used in municipal water purification, water filling plants and other commercial and industrial processes for over 100 years. Ozone is a fast oxidizing agent for metals such as iron and manganese and can be used initially for water pre-treatment. The content

of iron and manganese in water can be reduced to very low and safe levels by oxidation with ozone [2].
When treatment with O_3, disinfection occurs mainly at the point of contact of ozone with water[3]. For proper disinfection of water with chlorine or ozone, there must be sufficient chlorine or ozone residue in mg/l (i.e. parts per million or parts per million) in the water and sufficient contact minutes for disinfection to occur [4]. The pH of the water (how acidic or alkaline it is) along with turbidity and other contaminants play a role in the effectiveness of chlorine or ozone in disinfecting water from bacteria [5]. An Ozone water treatment can quickly disinfect water and kill bacteria and viruses, but unlike chlorine, it leaves no chemical chlorine residue behind. Ozone has been used successfully for water disinfection and can kill most bacteria, viruses and protozoa [6]. Widely used for bottled drinking water, ozonation is done by introducing ozone gas, which can be introduced at various stages of treatment depending on what you are trying to achieve[7]. Ozone is also widely used to disinfect bottled drinking water because ozone is soluble and effective in killing microorganisms by oxidizing their cell membranes [8]. Ozone provides consistent performance and is currently the most commonly used oxidizer and disinfectant for air and water treatment. Because ozone inactivates or quickly kills virtually all bacteria, cysts, and viruses, but leaves no lasting residue, ozone is the disinfectant of choice for most bottled water manufacturers [9]. After the ozone (O_3) has done its job in the filtration system, it is converted back into oxygen (O_2), resulting in highly oxygenated filter wastewater. Ozone quickly returns to its natural state of O2, so ozonized water can be used for drinking [10].
In all cases, the amount of ozone entering the water depends on the amount of ozone present in the air after it has passed through the ozone generator[11], on the surface presented at the gas-water interface [12].. Typically, the water flow rate is kept constant and the amount of ozone in the system is controlled by adjusting the voltage of the current causing the electrical discharge in the generator, or by adjusting the gas flow rate .In contrast, an ozone water treatment system is a stand-alone unit with no additional components needed to generate oxidation. In situations where a water softener or other water filtration equipment is required[13]. It is best to install a water ozone generator last in line to kill any bacteria that may be lurking in the water lines or other water treatment equipment[14].For example, many municipalities with surface waters containing the dangerous Cryptosporidium and Giardia currently use ozone water purification systems as their primary disinfection, as chlorine does not penetrate these protozoa and is therefore ineffective in killing them. There are over 5,000 installations around the world that use ozone to treat drinking water. We have

developed ozone systems for treating small to large industrial or commercial applications [15].

Ozone offers one of the best options for economical and reliable water treatment. Ozone water generators are a cheaper solution than chlorine, saline or other chemicals and can oxidize and kill almost all bacteria, viruses, and fungi present in the water, much faster and more effectively compared to chlorine and bromine[16]. Ozone is poorly soluble in water and is usually dissolved by a firm that relies on close air/water contact under conditions of very high turbulence, or by a diffuser that breaks the gas into very small bubbles that can remain in contact with the water [17].

2.Practical part

2. 1Collection of sample

9 samples of ozone sterile water were collected from local markets. Their acidity and electrical conductivity were evaluated, as well as solids such as turbidity, hardness and total solids, minerals such as calcium and potassium, and chlorine and bromine concentrations are evaluated. The analyzes were conducted in the laboratories of the Ministry of Science and Technology - Baghdad for the months of the following year (February, April and August) 2022.

2.2 Tests

Analyzes of ozone sterile water models were conducted (9) in chemistry laboratories at the Ministry of Science and Technology - Baghdad in 3 months of the year, which are Feb., Apr. and Aug.where the acidity function was measured with a device (PH meter), and electrical conductivity and total dissolved salts were measured by a Conductivity meter. The concentrations of calcium, potassium, fluoride, chlorine and bromine were determined by using the Spectrophotometer DR 2800.

3-Results and discussion

3-1-Acidity function and electrical conductivity

Acidity function for nine samples during the three months (February, April and August) all results were within the permissible limit (8.5-6.5) As shown in (Figure**. 1**) and (Table**.1**),

This indicates the efficiency of the method used for purification and may also be due to the low percentage of hydrogen in the raw water before the start of the purification process.

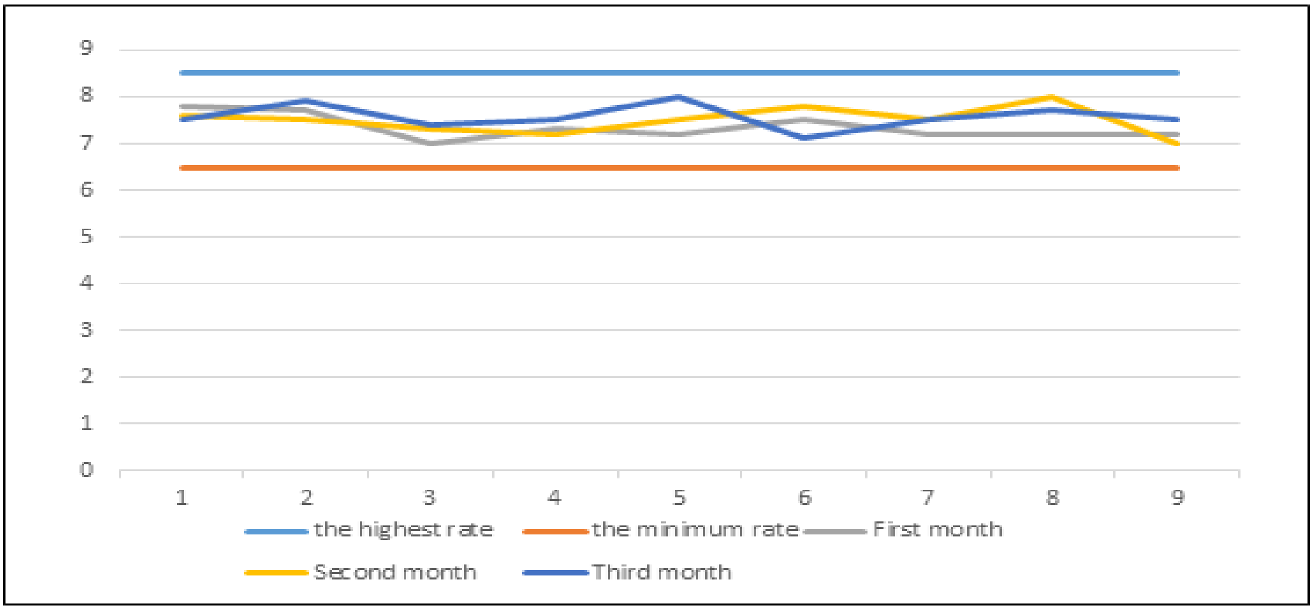

Figure.1 Laboratory results of pH testing

Table .1 Laboratory results of pH testing

Sample	Normal rang	Feb.	Apr.	Aug.
1	8.5-6.5	7.8	7.6	7.5
2	8.5-6.5	7.7	7.5	7.9
3	8.5-6.5	7.0	7.3	7.4
4	8.5-6.5	7.3	7.2	7.5
5	8.5-6.5	7.2	7.5	8.0
6	8.5-6.5	7.5	7.8	7.1
7	8.5-6.5	7.2	7.5	7.5
8	8.5-6.5	7.2	8.0	7.7
9	8.5-6.5	7.2	7.0	7.5

Electrical Conductivity (E.C.) It means the ability of water to electrical conduction, so it is directly proportional to the solutes, and the E.C. is affected by electrolyte present in aqueous solution[18]. results for all samples (1 to 9) came within the acceptable limits of electrical conductivity in bottled drinking water, which is (250 µs/cm) As shown below in (Figure.2) and (Table.2).

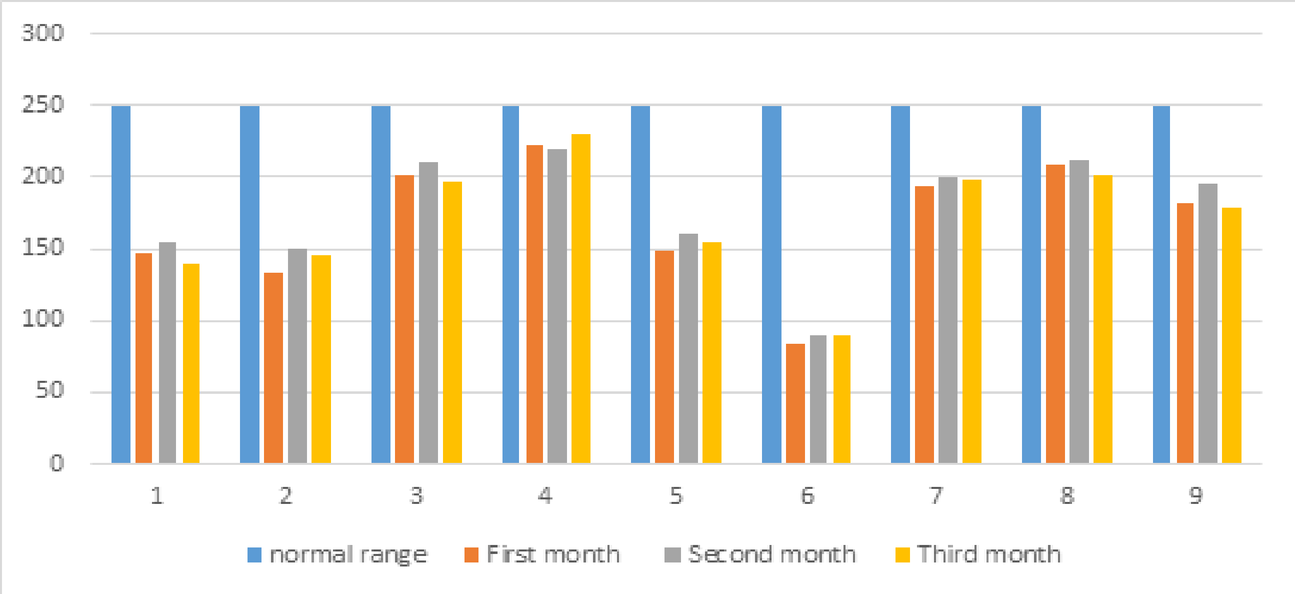

Figure.2 Laboratory results of electrical connection testing water.

Table .2 Laboratory results of electrical connection testing

sample	Reference	Feb.	Apr.	Aug.
1	250 µS/cm	**147**	155	140
2	250 µS/cm	133	150	145
3	250 µS/cm	201	210	197
4	250 µS/cm	223	220	230
5	250 µS/cm	148	160	155
6	250 µS/cm	84	90	89
7	250 µS/cm	194	200	198
8	250 µS/cm	209	212	202
9	250 µS/cm	181	195	179

3.2. Solid materials
3.2.1. Turbidity:

the samples, from (1 to 9). It came within the permissible limits for turbidity, which is (5NTU) As shown in (Figure **3**) and (Table **3**).

Turbidity is a measure that expresses the amount of substances that relate to water and describes the clarity of water and substances that are suspended in the water, and works to reduce the purity of the water and cause turbidity such as silt, mud and algae. Turbidity is a visual characteristic of the liquid and works to measure the clarity of the liquid levels of light diffused in the water column, Turbidity of water is measured in Nephelometric Turbidity Units, known as NTU for short. Turbidity may also be measured in Formazin Nephelometric Units, or FNU[19]. You can measure turbidity using a turbidity meter or sensor, which will use scatter-detection methods to quickly detect the levels of total suspended solids (TSS) in water. TSS - referring to waterborne particles that are larger than 2 microns - are the common culprits behind turbidity[20].

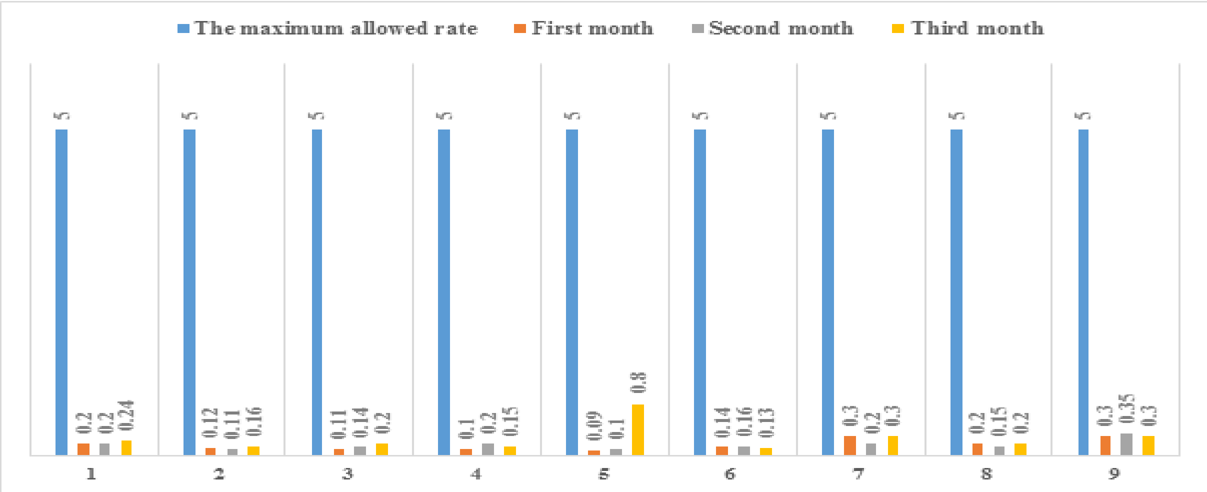

Figure 3. Laboratory results of turbidity testing

Table 3. Laboratory results of turbidity testing

Sample	Normal rang	Feb.	Apr.	Aug.
1	5 NTU	**0.2**	0.2	0.24
2	5 NTU	0.12	0.11	0.16
3	5 NTU	0.11	0.14	0.2
4	5 NTU	0.1	0.2	0.15
5	5 NTU	0.09	0.10	0.8
6	5 NTU	0.14	0.16	0.13
7	5 NTU	0.3	0.2	0.3
8	5 NTU	0.2	0.15	0.2
9	5 NTU	0.3	0.35	0.3

3.2.2. Total Hardness ($CaCO_3$)

The tests of the nine samples, it was found that (sample 3) its results were as follows: Feb.(188 mg / l), Apr(186 mg / l), Aug.(183 mg / l), while (sample 4) results were as follows (197 mg /l), (199 mg / l), (200 mg / l), and (sample 7) the results are as follows: (189 mg / l), (190 mg / l).), (200 mg / l) and for (sample 8) the results came as follows:

(199 mg/l), (197 mg/l), (202 mg/l), while (sample 9) came As follows: (202 mg/l), (204 mg/l) and (200 mg/l) and these results are higher than the standards set by the Iraqi government, which is (176 mg/l).
Cations have a charge that is positive and the charge can be +1 or higher. The total hardness of the water is actually the measure of the cations with a charge of 2 or more, i.e., "multivalent positively charged cations. This would include cations such as: calcium, magnesium, Iron, Manganese, Barium, Strontium, Aluminum, etc, but would not include the cations with a positive charge of 1 like Sodium, potassium, and Lithium.The total hardness of the water can be described as the combination of temporary (carbonate hardness) and permanent hardness (non-carbonate hardness). Temporary hardness is the hardness that is associated with anions like carbonate, bicarbonate, and hydroxide (OH-) because when the water is heated and ultimately boiled the water will lose some of the carbonate as CO_2 and the solution will become supersaturated with multivalent cations which will begin to form particles and precipitate from the water as a carbonate scale. This scale is typically white or gray, but may have other colors depending on the cation and can easily be removed by dissolving them in vinegar (a weak acid). Permanent hardness is the hardness that is associated with non-carbonate anions, like Chloride, Sulfate, and Nitrate [21].The (sample 1, 2, 5, 6) came within the permissible limit, which is (176 mg / l) ,Table and figure 4 show that.

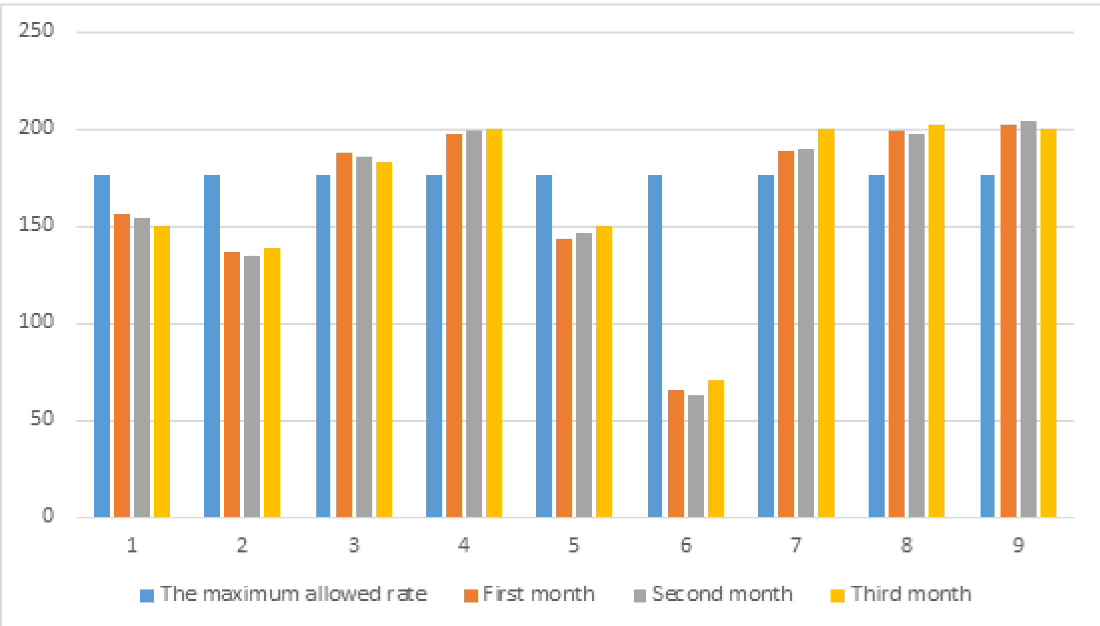

Figure. 4 Laboratory results of Total hardness testing water

Table 4 Laboratory results of Total hardness testing water

Sample	Reference	Feb.	Apr.	Aug.
1	176 mg/l	156	154	150
2	176 mg/l	137	135	139
3	176 mg/l	188	186	183
4	176 mg/l	197	199	200
5	176 mg/l	144	146	150
6	176 mg/l	66	63	70
7	176 mg/l	189	190	200
8	176 mg/l	199	197	202
9	176 mg/l	202	204	200

3.2.3. Total Dissolved Solids (T.D.S.)

The laboratory tests of the nine samples proved that they contain dissolved solids within normal limits, which are (150-500), where there is a direct correlation between total dissolved solids (T.D.S.) and salinity, as it is an indicator of dissolved salts in water, which has the ability to electrical conductivity. Total dissolved solids reach the water body either from natural sources such as rainwater running over rocky areas rich in salt content, or it comes from unnatural sources that result from the drainage of agricultural lands [22] As shown in **(Table.5)**.

Table.5 Laboratory results of Total dissolved solids testing water

Sample	Reference	Feb.	Apr.	Aug.
1	150-500 mg/l	**90**	91	96
2	150-500 mg/l	73	75	80
3	150-500 mg/l	144	144	140
4	150-500 mg/l	177	176	170
5	150-500 mg/l	93	94	99
6	150-500 mg/l	60	61	70
7	150-500 mg/l	140	141	145
8	150-500 mg/l	167	168	160
9	150-500 mg/l	110	111	120

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3.3 Minerals

3.3.1. Calcium (Ca)

samples (3, 4, 7, 8 and 9) have a significant increase in the calcium ion as shown in Figure 5 and Table 6. The rest of the models are within the permissible limit. The reason for the increased concentration of this ion may be the dissolution of limestone in raw water and other minerals.

Calcium is found in natural water and occupies the fifth place among the elements in terms of its abundance in natural water and is abundant in this water as a result of the dissolution of the compounds of the limestone crust in it, which is among the main elements causing water hardness and its concentration in water depends on the nature of the water resource and the type of treatment followed for water [23].

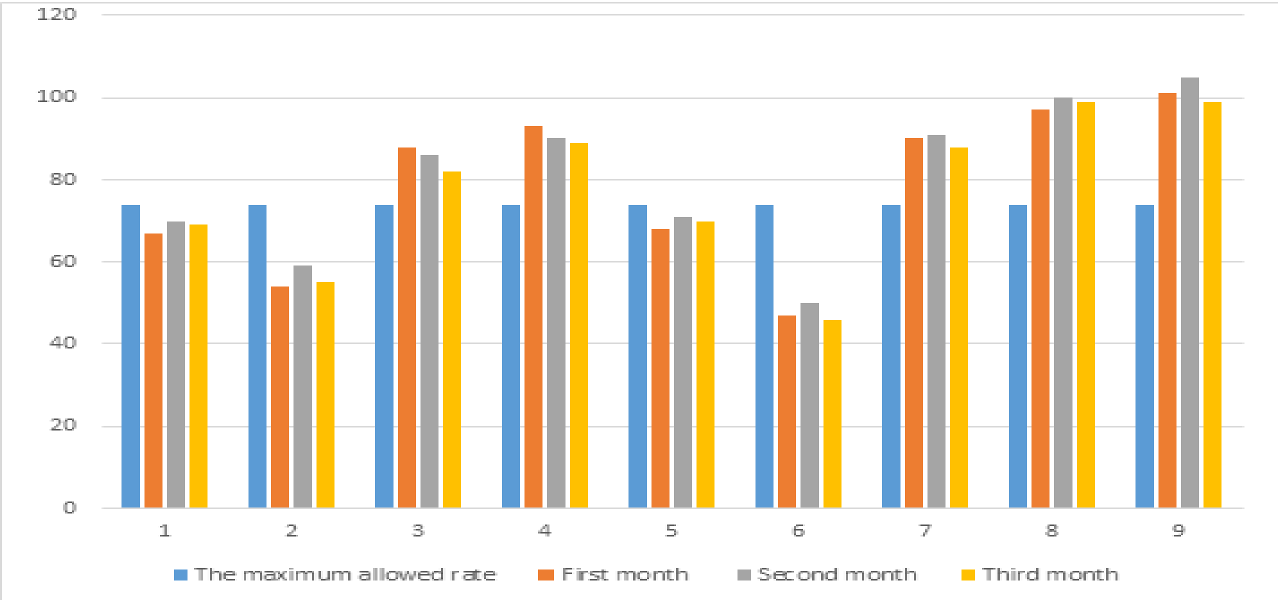

Figure .5 Laboratory results of Calcium ion testing water

Table.6 Laboratory results of calcium ion testing water

Sample	Reference	Feb.	Apr.	Aug.
1	74 mg/l	67	70	69
2	74 mg/l	54	59	55
3	74 mg/l	88	86	82
4	74 mg/l	93	90	89
5	74 mg/l	68	71	70
6	74 mg/l	47	50	46
7	74 mg/l	90	91	88
8	74 mg/l	97	100	99
9	74 mg/l	101	105	99

3.3.2. Potassium (K)

It was found that all samples contained normal percentages of potassium, except for (sample 9) whose result was (1.0 mg/l), which is very close to the permissible limit. (1.1mg/l) As shown in **(Table.7).** Potassium is a natural and essential element in plants and animals, and humans are exposed to it primarily through food. The most common source of potassium in drinking water are water softeners using potassium chloride. The use of a water softeners using potassium chloride can significantly increase the levels of potassium in drinking water, even at water hardness levels considered to be acceptable [24].

Table. 7 Laboratory results of Potassium testing water

Sample	Reference mg/l	Feb.	Apr.	Aug.
1	1.1	0.01	0.01	0.05
2	1.1	0.08	0.07	0.09
3	1.1	0.01	0.01	0.02
4	1.1	0.01	0.01	0.02
5	1.1	0	0	0
6	1.1	0.09	0.09	0.1
7	1.1	0.2	0.2	0.3
8	1.1	0.9	0.9	1.0
9	1.1	1	1	1.0

3-3-3- Fluoride (F)

The nine samples came within the acceptable limits for fluoride for three months (Feb., Apr.and Aug.) Figure 5 illustrates that. All sources of water have a natural amount of fluoride. The right amount of fluoride in drinking water helps protect against tooth decay. Drinking water includes all water used to drink or prepare drinks (including infant formula) and the water we use for cooking [25].

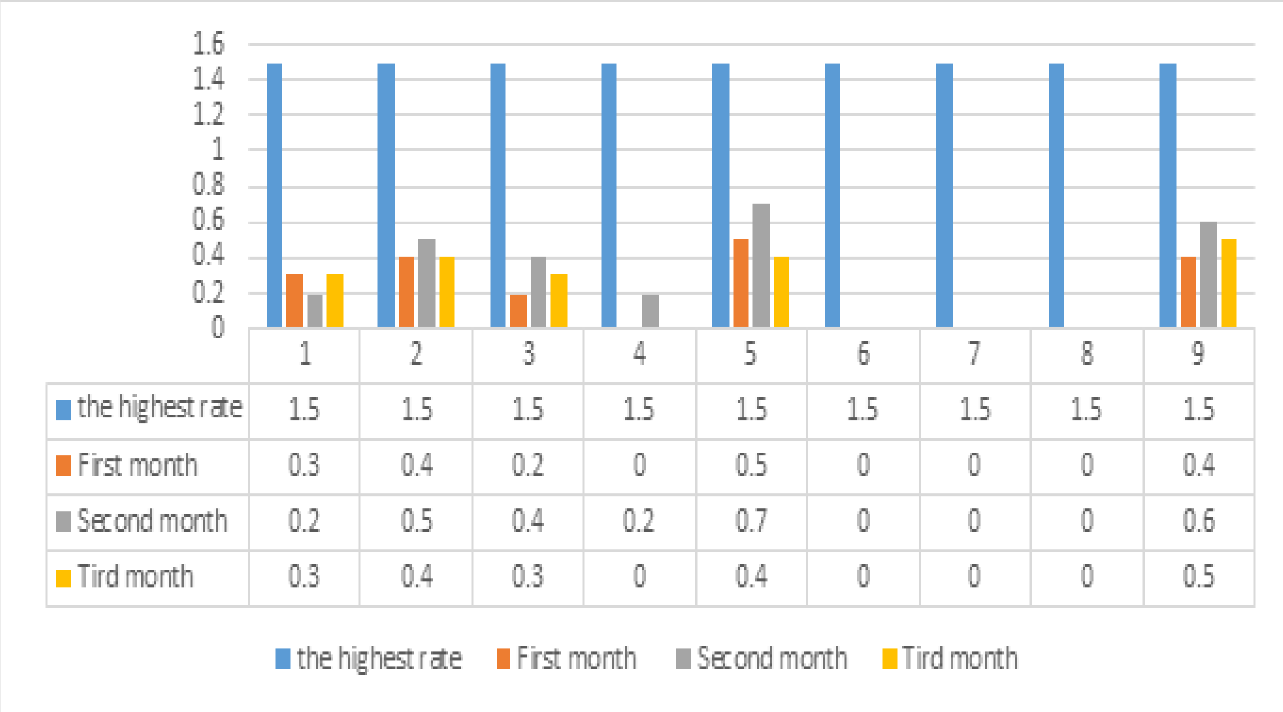

Figure :5 Laboratory results of Fluoride testing of water

3-4- Bromine

Bromate arises when ozone is used to treat contaminated water consisting of bromine naturally present in source water. These properties found in contaminated water include the pH water, amount of the bromide ion, the ozone degree and the reaction time, which affect the formation of bromate, a type of total bromine. Symptoms of bromate poisoning can include vomiting, diarrhea, nausea, and nerve and kidney problems. It should be noted that these symptoms usually involve the consumption of water containing more than a thousand times more bromate than regular drinking water. In addition, exposure to very high levels of bromate can acquire the effects of hearing loss and the nervous system[26]. in the monthly averages , bromate concentrations in the local bottled drinking water models, where (Sample 9) recorded an increase in the bromate percentage for the three months, higher than the normal (0.01 mg/l), while the results of the rest of the samples (1, 2, 3, 4, 5, 6, 7, 8) came Bromate-free, which is an excellent indicator of the effectiveness of ozone in the oxidation and sterilization process (Table 8) illustrate that.

Table 8: Laboratory results of Bromate Testing water

sample	Normal rang		Feb.	Apr.	Aug.
9	**Total bromine Br2**	0.01mg/l	0.02	0.04	0.03
	free bromine Br2	0.01mg/l	0.01	0.02	0.02

4- Conclusions

It is clear from the values obtained when conducting a chemical and physical evaluation of 9 models of ozone-sterilized water that this sterilizer and oxidizer has excellent effectiveness, as the acidity, electrical conductivity, turbidity, bromine, fluoride and calcium are within the permissible limits and proven in international and Iraqi standards.

It is necessary to conduct these assessments throughout the year and using ozone technology, which has proven its effectiveness, as we still use to this day the chlorination method, which contains many negatives and is reflected in the lives of citizens.

The presence of some deviations in the concentrations that have been evaluated indicates that not all the water in the markets, whether of local or global origin, is a healthy and safe alternative.

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