KOVALEN: Jurnal Riset Kimia

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Comparative Estimation of Some Contaminates in Products of Drinking Water Companies and Government Stations in the City of Mosul

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Abstract. Recently, the concentrations of heavy metals have increased in water sources, soil and air, and their symptoms have clearly appeared on living organisms and the serious effects they leave on humans, animals and even plants. Therefore, it has become necessary to periodically monitor these metals, including nickel (Ni), cadmium (Cd), lead (Pb) and chromium (Cr). However, the problem does not stop with heavy metals, as there are other parameters that are closely related in one way or another, such as hardness, pH, total dissolved solids (TDS) and even conductivity (EC). All of these are present in the water under study, in addition to the Microbiological Assessment test to search for pathogens. The environment of Mosul city was chosen as a source for collecting samples from three categories: local water projects, reverse osmosis water sales systems, in addition to companies accredited for sterilizing, bottling and marketing water. the results were within the limits established in the regulations of international organizations, lead, cadmium, nickel, and chromium, they were, in order:(16.2, 86.2, 154.1, 79.7×10^{-3}), while conductivity was less than 800 µs/cm, and TDS were less than 300 µg/ml , while the pH was within the moderate basic level, as the values ranged between (7.41 - 8.02), while the water hardness was within the acceptable range (acceptable limit: 100-300 µg/ml).

Keywords: *atomic absorption spectrometer, heavy metals, total dissolved solids, conductivity, microbiological assessment, hardness.*

Abstrak. Baru-baru ini, konsentrasi logam berat telah meningkat di sumber air, tanah dan udara, dan gejalanya telah jelas terlihat pada organisme hidup dan efek serius yang mereka tinggalkan pada manusia, hewan dan bahkan tumbuhan. telah menjadi perlu untuk memantau logam-logam ini secara berkala, termasuk nikel (Ni), kadmium (Cd), timbal (Pb) dan kromium (Cr). Namun, masalahnya tidak berhenti pada logam berat, karena ada parameter lain yang terkait erat dalam satu atau lain cara, seperti kekerasan, pH, total padatan terlarut (TDS) dan bahkan konduktivitas (EC), Semua ini ada dalam air yang diteliti, di samping uji Penilaian Mikrobiologi untuk mencari patogen. Lingkungan kota Mosul dipilih sebagai sumber untuk mengumpulkan sampel dari tiga kategori: proyek air lokal, sistem penjualan air osmosis terbalik, di samping perusahaan yang terakreditasi untuk sterilisasi, pembotolan dan pemasaran air. Hasilnya berada dalam batas yang ditetapkan dalam peraturan organisasi internasional, timbal, kadmium, nikel, dan kromium, yaitu, secara berurutan: (16,2, 86,2, 154,1, 79,7×10-3), sedangkan konduktivitas kurang dari 800 µs/cm, dan TDS kurang dari 300 µg/ml, sedangkan pH berada dalam tingkat basa sedang, karena nilainya berkisar antara (7,41 - 8,02), sedangkan kesadahan air berada dalam kisaran yang dapat diterima (batas yang dapat diterima: 100-300 µg/ml).

Kata kunci: *spektrometer serapan atom, logam berat, total padatan terlarut, konduktivitas, penilaian mikrobiologi, kekerasan.*

Received: July 31, 2025, Accepted: August 16, 2025
Citation: Nejres, A. M. (2025). Comparative estimation of some contaminates in products of drinking water companies and government stations in the city of Mosul. *KOVALEN: Jurnal Riset Kimia*, 11(1): 12-24.

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https://doi.org/10.22487/kovalen.2025.v11.i1.17787

INTRODUCTION

Drinking water is a basic human right for the survival of people, regardless of their ethnic and religious diversity. Given the increasing population and the importance of drinking water, providing a safe and plentiful supply has become a top priority, ensuring a stable human health and social well-being. This results in a society with low morbidity and mortality, accompanied by environmental and social balance (Leeuwen, 2000). The World Health Organization (WHO) reported that half of the population in developing countries suffers from problems with the quality of water suitable for human consumption, whether chemical or microbiological (World Health Organization, 2017). To avoid this, strict standards must be established based on an assessment of these problems, and guiding protocols for drinking water quality must be developed by the World Health Organization and countries with reform policies to ensure consumer safety (Li and Wu, 2019).

Given the increasing demand associated with population growth, which results in uncontrolled consumption of drinking water, it is necessary to evaluate the various sources of service (potable water) by assessing the quality of that water based on the level of associated pollution (Al Yaqoutm, 2003) .

Pollutants are divided into natural pollutants consisting of inorganic chemical compounds (arsenic, chloride, manganese, iron, cobalt, cadmium, lead, calcium, etc.) and organic/microbiological pollutants resulting from human and environmental activity (Ghrefat *et al.*, 2014; Szewzyk *et al.,* 2000). Although, these minerals are essential for humans, the quantities available in water are increasingly depleted and have a negative impact (USEPA, 2015).

Given the importance of the topic, previous studies have examined the quality of drinking water. One study examined the efficiency of drinking water produced by the Basra Iraq water treatment plant (Eassa and Mahmood, 2012), as well as the use of the water quality index to study the quality of water for the city of Baghdad and Mosul (Flaieh *et al.*, 2014; Kannah and Shihab, 2021; Khudair, 2013) . The effect of heavy elements in tributary rivers on drinking water sources in Mosul city,iraq was also studied (Al-Sarraj and Jankees, 2014).

Despite previous studies conducted on various types of drinking water sources or water directly intended for human consumption, which indicated the presence of contaminants, including heavy metals, at various concentrations and types, and reviewed the factors affecting them, their sources, and their risks, there remains an urgent need for continued research as a measure to ensure safe drinking water.

MATERIAL AND METHODS

Location

The study area was defined within the city of Mosul, Iraq (36°20'29.0"N 43°08'39.7"E). The study samples were selected from houses connected to water treatment plants located along the river. These plants were produced in the 1980s and were designed based on the concept that the quality of the Tigris River was considered relatively good. New treatment plants were constructed according to official specifications and measurements approved by the relevant government agencies. These were based on the concept that the Tigris River had lost a significant amount of its quality due to climatic factors, Turkish dams, and the excessive discharge of sewage into the river and fish farms. Other samples were collected from private treatment units for bottling drinking water located throughout the study area, which treat water received from the aforementioned treatment plants. In addition, samples were selected from drinking water bottling companies available in the markets of the study area. Table 1 and Figure 1 showed a map of the sample collection site.

Table 1. Location of study area in Mosul city

Code	Name	Location
OM1	ALSIDIQ[1]	36.395981, 43.144540
OM2	ALARABI[1]	36.399298, 43.118712
OM3	ALNOOR[1]	36.363911, 43.185379
OM4	17TAMOZ[1]	36.366598, 43.087349
DO1	ALSIDIQ[2]	36.391579, 43.161770
DO2	ALSHORTA[2]	36.381215, 43.132401
DO3	ALZOHOR[2]	36.378562, 43.182278
DO4	TANAK[2]	36.336287, 43.066049
DO5	OLD MOSUL[2]	36.341929, 43.127604
DO6	ZAWRAA[2]	36.362200, 43.095245
AW1	DEFAF[3]	Company*
AW2	SAFEE[3]	Company*

1. Water filtration plant using Reverse Osmosis - RO system
2. Local water projects
3. Drinking water production companies in the city

Figure 1. The map of study area in Mosul city

Instrumentation and Methods

Samples were collected and classified in Table 1. Atomic absorption spectrometry (AAS) *(novAA350-analyitkjena-Germany)* was used to instant estimation of water samples collected in glass bottles. While a conductivity meter, total dissolved solids (TDS), pH meter were measured by *(multifunction model EZ-9909SP-China)*. Water hardness method was used to measure the standard calibration method *(Use a standard EDTA solution to titrate a water sample after adding Eriochrome black as an indicator. The indicator changes color from burgundy red, indicating the presence of calcium and magnesium ions, to blue as a result of the disappearance of these ions from the solution)*. Using the statistical analysis program *SigmaPlot 14.5 with windows 11 Version 24H2 for x64 and Excel office 2020.*

Microbiological Assessment

Implemented nutrient agar (NA) methodology per ISO 6222:1999 for preliminary screening of reverse osmosis system water, with explicit recognition of its scientific limitations in low-nutrient matrices. Samples were collected after six-hour stagnation in sodium thiosulfate-preserved containers and processed within six hours per ISO 19267:2019 guidelines. NA plates (pH 6.8 ± 0.2) were inoculated with 100 mL filtered samples and incubated at 30°C for 24 hours to accommodate psychotropic organisms prevalent in ROS environments.

RESULT AND DISCUSSION

Heavy Metal Concentrations in Water Samples

The toxicity of heavy metals is due to their biochemical role in the metabolic processes and physiological functions of living organisms. Any disturbance in their presence within certain ranges shows its effects on the kidneys, brain damage, mental retardation, cancer, and even death (Nejres and Mohamed, 2020; Singh *et al*., 2011). Among the metals whose concentrations have been studied (Lead, Cadmium, Nickel and Chromium). The Table 2 shows the standards issued by international organizations and committees on water quality (Anggraeni *et al.*, 2024).

Tests were conducted on 12 samples under study to determine nickel, chromium, cadmium, and lead. Compared to the results from institutions, associations, and state organizations shown in Figure 2, the results were significantly lower than the permissible levels. This indicates that the water, according to the elements studied, is of good quality and suitable for human use Table 3.

Table 2. Guidelines and international standards for permissible heavy metal concentrations (μg/ml)

H.M. (μg/ml)	Pb	Cd	Ni	Cr
USEPA[1]	15	5	NA	50
WHO[2]	10	3	70	50
ADWG[3]	10	2	20	50
ECE[4]	10	3	20	50
FTP-CDW[5]	10	5	NA	50
PCRWR[6]	50	10	20	50

1. United Stated Environmental Protection Agency;
2. World Health Organization;
3.Australian Drinking Water Guidelines;
4. European Commission Environment;
5. Federal-Provincial-Territorial Committee on Drinking Water Health Canada;
6. Pakistan Council of Research in Water

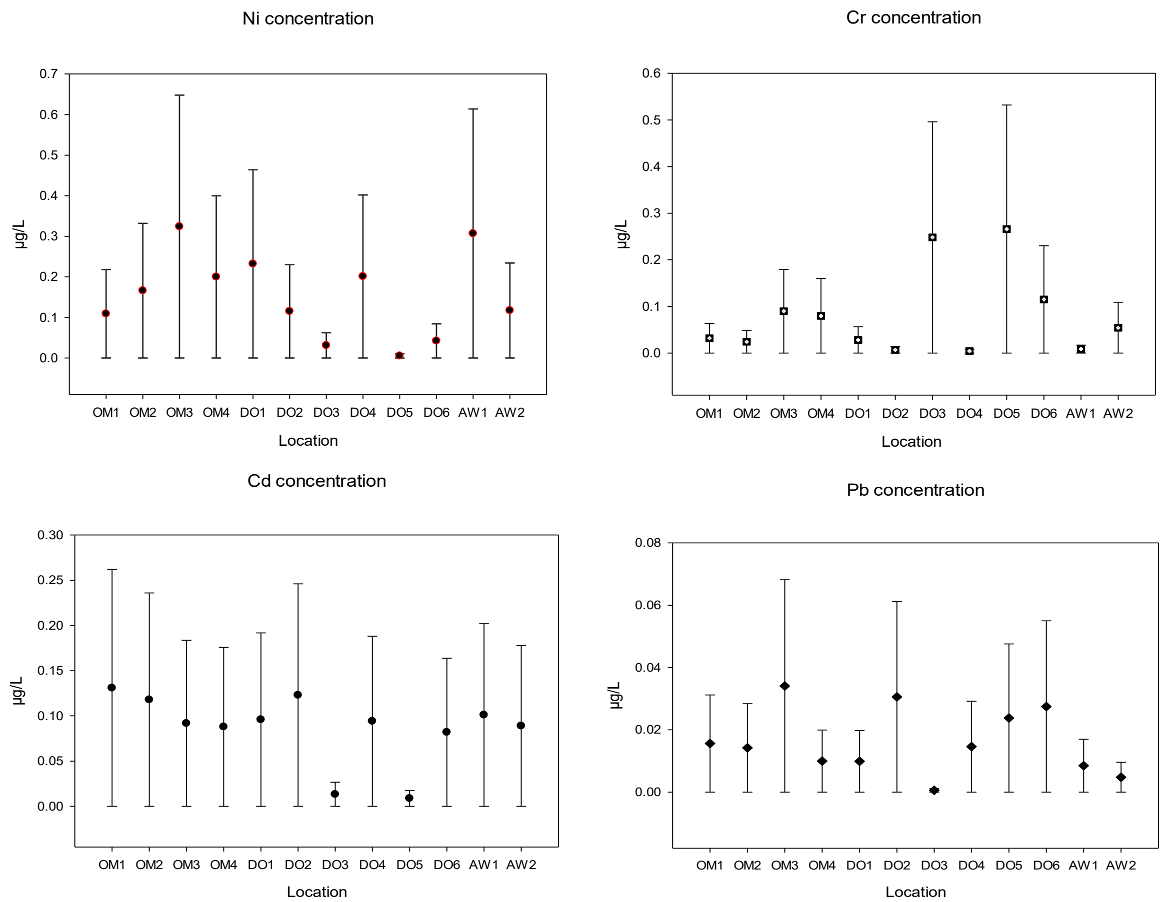

Figure 2. The concentrations (ppm) of heavy elements (Ni), (Cd), (Cd), and (Pb)

Table 3. Statistical analysis of heavy metal values

Code	Heavy metals μg/mL*10^{-3}			
	Pb	Cd	Ni	Cr
OM1	15.6	131	109	31.8
OM2	14.2	118	166	24.4
OM3	34.1	91.8	324	89.7
OM4	9.96	87.9	200	79.9
DO1	9.9	95.9	232	28.2
DO2	30.6	123	115	7.05
DO3	0.57	13.3	31.1	0.248
DO4	14.6	94.1	201	4.3
DO5	23.8	8.75	5.3	266
DO6	27.5	81.9	42.1	115
AW1	8.48	0.101	307	8.6
AW2	4.78	88.9	117	54.5
SD	10.58	38.28	103.35	89.96
mean	16.2	86.2	154.1	79.7
max	34.1	131	324	266
min	0.57	8.75	5.3	4.3

Heavy metal lead

Lead (Pb) is considered one of the most important elements found on the surface of the Earth's crust due to its harmful effects and high degree of toxicity (Anggraeni *et al.,* 2024). Its presence has been permanently diagnosed in industrial areas, such as refining operations, battery factories, and human activity waste (Ara and Usmani, 2015). The living organism is exposed to it through drinking water, contaminated food, and air (Can *et al.*, 2008). Its direct impact on the biochemical and physiological performance of humans has been proven, as it has a significant impact on the liver (Singh *et al.*, 2018) , damage to red blood cells (González Rendón *et al.*, 2018).

Heavy metal cadmium

Cadmium (Cd) is a metal with a cumulative effect, as it works, if present, to change the physical and chemical properties of the soil and thus the plant community, and it also has the potential to penetrate deep and settle in groundwater (Li *et al.*, 2024; Ye *et al.*, 2022). It concentrates and its symptoms appear in the liver and kidneys, causing chronic diseases in the long term(Venter et al., 2015) as it works to oxidize hepatic fats and microsomal fats and deplete glutathione (Karmakar *et al*., 2000).

Heavy metal nickel

Nickel (Ni) is an essential component of water, the concentration is tower than 100 and 0.005 μg/ml (Hassan *et al.*, 2019), and in plants as an essential element at a concentration of less than 0.05–10 μg/ml (Ragsdale, 1998). Low concentrations of nickel contribute to a positive effect on biochemical and physiological functions. Conversely, when its concentrations are high, it becomes a toxic factor for the immune system, and its high levels have resulted in some cardiovascular diseases, lung fibrosis, and respiratory cancer, in addition to a disruption of mitochondrial functions (Genchi *et al.*, 2020; Hasinur Rahman *et al.,* 2005) .

Heavy metal chromium

Chromium (Cr) is abundant in the earth's crust and its toxicity depends on its chemical state. It is biologically toxic, especially when its valence is trivalent and tetravalent (Dayan and Paine, 2001; DG, 1999). The toxicity of chromium was studied in the 1980s and the effect of increasing its concentration. It was observed that increasing the concentration of its trivalent compounds led to an increase in lung cancer cases. It also has the ability to enter cells through their membrane system, causing damage to those cells (Eastmond *et al.*, 2008). While increasing the concentration of hexavalent chromium causes what is known as functional oxidation processes in the liver and kidneys and damage to blood cells (Gammelgaard *et al.*, 1992). Also, its high percentage in water causes skin damage (Kim *et al.*, 2015).

Chlorine in Water

From Figure 3, it is clear that the free chlorine concentration falls within the permissible range set by the World Health Organization regulations of less than 500 μg/mL. That the residual chlorine content is harmless to health, and its continued presence prevents the growth of microorganisms, thus ensuring consumer protection.

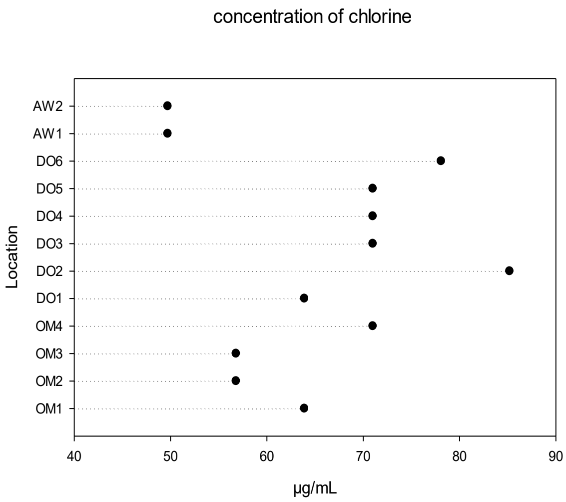

Figure 3. Concentration of chlorine in sample's water

Chlorine has several risks to water, living organisms, and plants. It generally raises the acidity of water (Robinson *et al.,* 2017), reduces biological diversity (Szklarek *et al.*, 2022), lowers soil porosity, thus reducing vegetation cover (Garakani *et al.*, 2018; Zítková, *et al.,* 2018). Although its presence is beneficial, when it rises to a certain level, it plays a negative role. Studies have confirmed that it plays a role in diseases of weak immunity, high blood pressure, chronic heart failure, kidney disease, and tissue infarction. Therefore, it is necessary to monitor it, as the World Health Organization has confirmed that chlorine limits should fall within a range of less than 500 μg/L (Singh *et al.* 2010; World Health Organization, 2017).

Total Hardness

The results obtained from the water content versus EDTA correction process shown in Figure 4, that the samples under study fall within the permissible limits (Acceptable limit: 100-300 μg/mL, and maximum permissible limit: 500 μg/mL (WHO, 2011).

Total hardness is important in determining the quality of water because it causes an unpleasant taste when it reaches high concentrations, in addition to its effect on the foam formation of cleaning materials due to the precipitation of calcium and magnesium soaps. Magnesium and calcium ions are considered among the most important causes of hardness (Alsaffawi *et al.*, 2018), but their role goes beyond that. If the concentration of the two ions decreases to a certain percentage, this leads to the corrosion of pipes (Akram and Rehman, 2018). Its decrease also leads to certain diseases, including osteoporosis and nervous disorders (Rosborg and Kozisek, 2016). Also, the increase in these ions causes kidney stones and arthritis (Schwartz *et al.*, 2002). It is necessary to test them in order to determine the quality of the water used for drinking.

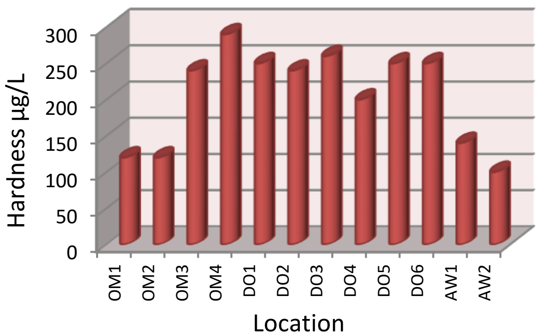

Figure 4. Hardness water level in samples

Acidic Function

The pH tests revealed that the water samples under study were within the range of moderate to basic, which is included within the physical balance, leading to many positive aspects and shape (Figure 5).

To achieve balanced body health, blood and tissue fluids must be maintained within moderate limits. Several studies have confirmed that the body works at high efficiency when the blood pH is close to the alkaline-neutral limits of 7.36. This can be achieved by relying on nutrition as a fundamental pillar within the range of alkaline foods and drinking alkaline water (Patel *et al*., 2014; Yehia and Said, 2021). On the other hand, any influence of the index towards the acidic values of water may lead to an imbalance in the body, causing fatigue, muscle pain, and indigestion (Patel *et al*., 2014) premature aging (Weidman *et al.,* 2016) weight gain (Nabata *et al.,* 1992) decreased bone mass (Sebastian *et al.,* 1994). Therefore, evaluating the pH index of water is essential to detect water quality.

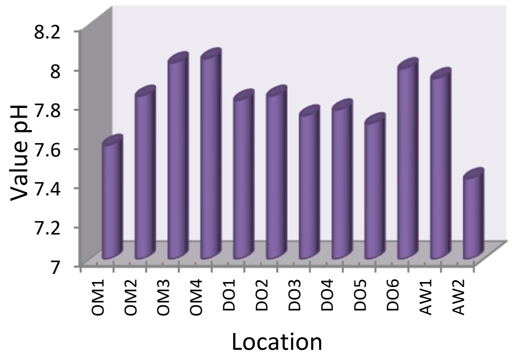

Figure 5. Acidity scale in study samples

Total Dissolved Solids and Electrical Conductivity

TDS is considered one of the important physical parameters used in evaluating water quality as it affects the performance of drinking water (Adjovu *et al*., 2023; Adjovu *et al*., 2023). It can be defined according to the American Public Health Association as the components of highly dissolved solids in a water sample passing through a porous membrane with a diameter of 2.0 micrometers or less under specific conditions (Adjovu *et al.,* 2023; Association, 2017). The periodic evaluation of these substances is of great importance to understand how they are affected by natural environmental variables and others resulting from human activity and thus negatively impact water (Gootman and Hubbart, 2023). Although these substances are not considered a major pollutant, their increased concentration leads to a change in the taste of water and causes corrosion and sedimentation in vessels and disturbances within the natural environment (Gootman and Hubbart, 2023). Table 4 shows the classification of water quality according to the World Health Organization based on TDS (WHO, 2011).

Table 4. Water quality based on the amount of total dissolved solids (TDS)

TDS µg/mL	Quality
50	Very pure
<300	Suitable for drinking
300-600	Altered taste, not harmful
<1000	Undesirable/causes sedimentation
>1000	Potentially dangerous

The electrical conductivity (EC) of water is a measure of its ability to conduct electrical current. Conductivity is related to TDS, conductivity increases with the increase in ions and dissolved molecules in the water (Clasing *et al*., 2023), which are two of the basic components of TDS. It has also been observed that increasing temperature plays a role in conductivity, due to the faster movement of ions. The same concept applies to dissolved molecules and their effects upon rising temperatures. This indicates a relative relationship between the two factors, with these factors being affected by the intensity of salinity, the activity of dissolved ions, and their ionic strength, as confirmed by researchers (Dewangan *et al.*, 2023; Klemas, 2015). However, in freshwater environments, the correlation between electrical conductivity and TDS is direct. based on the values in Table 5. water quality can be assessed (Rusydi, 2018).

Table 5. Quality of water based on EC parameter

EC µs/cm in (25c°)	Quality of water	K=TDS /EC[a] (µg.cm/ml.µs)
1.0-10	Distillate	0.50
300-800	Fresh	0.55-0.75
500-3000	Natural	0.55
45000-60000	saw	0.70
65000-85000	Brine	0.75

[a] TDS/EC ratio (k value): increase along with the increase of ions in water(Hayashi 2004)

According to the instructions in the Tables 4 and 5, based on the results obtained and listed in Table 6. It confirms to us, as an extension of the previous results, that the water quality is good. Figure 6 shows the results of the mesh plot confirms that the central results meet at the center of the circle, represented by the value of K, the other part of it, represented by the scatter plot, confirms that there is a close relationship between conductivity and TDS. This tends to explain that in fresh water the two parameters have a linear relationship.

Table 6. The results obtained for EC, TDS, and K

Code	OM1	OM2	OM3	OM4	DO1	DO2
EC	211	469	438	411	453	469
TDS	107	235	219	205	229	235
K	0.5	0.5	0.5	0.49	0.49	0.5
Code	DO3	DO4	DO5	DO6	DO7	DO8
EC	442	437	458	456	213	72
TDS	221	219	229	228	105	105
K	0.5	0.5	0.5	0.5	0.49	0.5

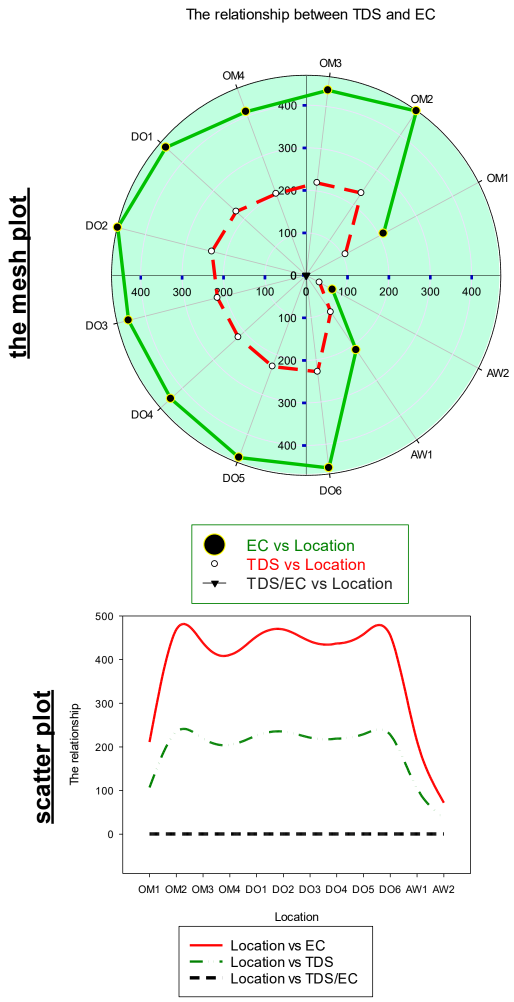

Figure 6. The mesh plot and scatter plot of relationship between EC and TDS

Microbiological Assessment of Water

After biological evaluation of the samples, Searching for Total Plate Count, fecal Coliform, and *Escherichia coli* bacteria, which are known to be responsible for typhoid, chlorella, and enteritis. All samples yielded negative results (no color indicator), with the exception of ALZOHOR and SAFEE, which yielded positive results indicating the presence of bacteria (appearance of a color indicator) (Figure 7).

Detecting the most common types of bacteria (fecal Coliform, and *Escherichia coli* bacteria,) are extremely important due to their significant role in intestinal inflammatory diseases, chlorella, and enteritis. Furthermore, increasing their cumulative concentrations over time leads to elevated pH levels (Saunders *et al.*, 2012). Therefore, it is important to detect them as one of the causes of deterioration in water quality and their impact on other parameters.

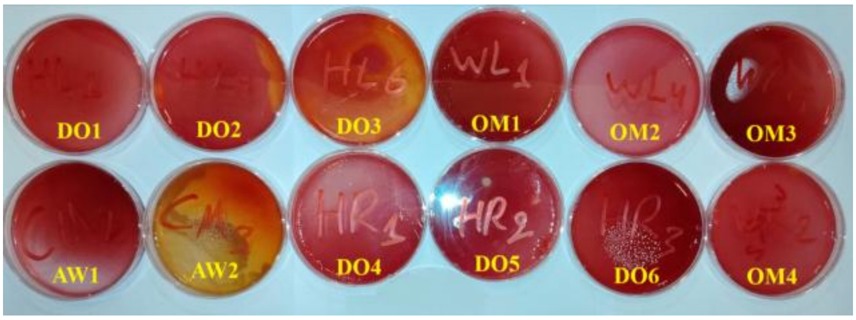

Figure 7. The positive and negative results for bacterial detection

CONCLUSIONS

From the results presented in the tables and figures, it is evident that the local water purification projects and the reverse osmosis drinking water plant are comparable in quality to the water bottling companies. Therefore, all of them, without exception, fall within the limits that can be described as good water quality. In Table 3, there is a discrepancy between the highest and lowest values for heavy metal across the various measurement areas. This is due to the method of filtering and processing the samples. This is confirmed by the standard deviation, as the dispersion is within good limits, according to the concept of "if the dispersion is less than 10%, it is good, and more than 30% compared to the average, it is poor" (Bulmer, 1979; Kumar and Dua, 2009).

Author recommends that soil and air studies be conducted, similar to the water-based study of heavy metals. These efforts should be conducted periodically, as recommended by international organizations and institutions. Given global warming and rising temperatures, a study should be conducted into the impact of temperature on the parameters affecting water and soil quality. This study should be conducted under different climatic conditions to determine the impact, if any.

ACKNOWLEDGMENT

I would like to thank and appreciate everyone who helped me complete my research requirements at the University of Mosul, College of Pharmacy.

CONFLICTS OF INTEREST STATEMENT

No conflicts of interest

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