

Research Article

Evaluation of the carbon content of reservoir water at the University of Technology

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Abstract

Water tanks are important and necessary for storing and subsequently using water for various purposes in both private and public buildings. To maintain good water quality, these tanks must be regularly maintained and cleaned. Otherwise, they can cause numerous health problems for users and render the water unfit for human consumption. This study assesses the potential presence of organic carbon in the water tanks of the University of Technology in Baghdad. Water samples were collected from tanks within the university, as well as from the main drinking water supply sources. The main concept of the assessment was the presence of organic carbon in the tank water due to the accumulation of solids and impurities inside the tanks and the possibility of bacteria gathering as a result. The total coliform test, Escherichia coli test, and total live bacterial count (CFU/ml) were performed. Some chemical and physical parameters were also examined (pH, electrical conductivity, salinity, total dissolved solids, turbidity, total hardness, calcium, magnesium, and Biological tests (BOD, COD) using different devices to assess water quality and obtain an index of organic carbon in it. After obtaining the results, elevated levels of Ca, EC, and TDS were found in some samples. Bacterial growth was also observed at the main supply point, while BOD and COD values were within normal and acceptable limits. Overall, the water quality can be classified as good.

1. Introduction

Water storage tanks provide and ensure a continuous supply of water and the water needed for various purposes, including all domestic and industrial needs and uses [1]. These tanks are typically used as primary containers for preserving and storing water for future needs, allowing communities and users to overcome water scarcity problems, ensure water availability when needed, and maintain a steady water supply in areas where obtaining the required quantities of water is difficult.

The material used, design, construction and maintenance of water storage tanks are critical to ensuring the quality and safety of the stored water [2]. The water supply system transports water from its sources to its users, provides its main services to the industrial environment, and plays a crucial role in responding to emergencies [3]. Storage tanks are often among the most prominent and important components of water supply systems. The primary goal of the system should be to provide ample service to all residents and users to improve the quality of the water supply [4, 5]. According to the World Health Organization [6], Safe drinking water is described as having microbiological, physical and chemical properties that meet the requirements of the World Health Organization. To be deemed safe, coliform bacteria should not be detected in 100 mL water samples, and their presence in drinking water suggests the risk of harmful bacteria. The recommendations specify that water with turbidity readings of less than 5 NTU can be deemed safe for drinking [7]. Although water tanks are of great importance in

providing multiple benefits in the distribution system, they also have disadvantages that clearly affect the quality of the water, as shown in Table 1.

Table 1: Water storage tank advantages and disadvantages

Advantages	Disadvantages
Pumping rates equalization	The water of poor quality
Equalize the supply and demand of water	Inadequate mixing, insufficient water turnover, and dead zones
Acquire water in situations like fires and pump failures.	DBP* formation
Reduce pressure fluctuations during times of high use.	Loss of free chlorine residual
Pressure should be increased in the distribution system.	The disparity in tank capacity and demand
Water sources blending	stratification of water and stagnation
Provide water for industrial demands	Utilization of chemicals used for disinfection in excess
Storage of water from a water treatment plant	Pathogenic contamination pathway

* DBP: Disinfection by- Products.

A study by Schaefer in 2010 showed that although the water quality in storage tanks made of polyethylene, fiberglass and concrete was not significantly different, the level of microbial contamination varied for the type of those tanks as measured by *Escherichia coli* bacteria count ($p = 0.082$) [8]. Several problems may occur due to water stagnation at the bottom of tanks, such as problems related to physical properties like odor and taste, loss of residual chlorine and water color, elevated levels of disinfection by-products (DBP) to levels unsafe for drinking water, as well as microbiological contamination that may seep into the water supply [9–11].

Special protocols for heat treatment and a suitable method for water storage must be adhered to and followed to reduce the risk of developing serious diseases. The study highlights the need to manage drinking water to reduce health risks. Physical problems and challenges include impurities, turbidity, and water temperature resulting from sediment buildup, while chemical problems include corrosion and damage to the tank lining or coating, loss of chlorine, growth of secondary disinfection byproducts, sedimentation, and salts [12].

American Water Work Associate (AWWA) Research Foundation in 2006 claimed that a well-mixed tank has a consistent water temperature. The temperature of the tank's water also influences the rate at which chemical reactions occur [13]. With every ten-degree Celsius increase in temperature, the rate of decomposition of residual chlorine and the formation of secondary disinfection products doubles. Maintaining residual chlorine levels in the tank becomes more difficult, secondary disinfection product formation increases, biofilms proliferate, and the likelihood of pathogenic contamination rises with increasing water temperature [13]. The most important health problem related to water storage tanks is the chemical pollution generated by the materials used to construct these tanks [11]. Galvanized tanks may cause the release of heavy metals like Zn and Cd [14]. Aluminum tanks, with time, can affect the quality of the stored water [15]. Some harmful organic materials may contaminate water stored in plastic tanks [16, 17]. The results of a study conducted on galvanized, plastic and aluminum storage tanks showed that plastic tanks had the least impact on water quality with respect to total dissolved solids and electrical conductivity parameters [18]. It was found that most of the biological, physical and chemical properties of the water fall within the limits of the standards of the World Health Organization, with the exception of total heterotrophic bacteria, which were found in shockingly high concentrations in water stored in various tanks during the evaluation of storage tanks made of steel, plastic and concrete [19]. The maximum tank water retention duration in various jurisdictions ranges from one to five days [20]. According to Table 2, water tanks can have a design life of up to 100 years with good preventative maintenance; however, this depends on the tank material [21].

Table 2: The design life of water storage tanks [20]

Drinking Water Component	Years
Water Storage Tank	25-100
Concrete	50-80
Wood	25-50
Metal	50-100
Fiberglass	50-80

There are many different ways to maintain water tanks and water quality through continuous cleaning and sterilization. Routine cleaning and maintenance can be carried out once a week, periodic inspections once a year, and comprehensive rehabilitation and maintenance every three to five years [22].

The Water Quality Index (WQI) is an important criterion used to assess the combined impact of different water quality criteria on the overall quality of drinking water [23]. This method can be used to allow us to determine the state of water quality without the need to explain and clarify individual parameters. It provides a single numerical value to assess the quality of water [24]. Therefore, it is widely used for water resource management. Many researchers have used Water Quality Index (WQI) models specific to their regions to improve the efficiency of groundwater quality assessment [25].

Since the storage time of water is directly proportional to the storage volume, excess water should not be stored. The following calculation can be used to estimate the average time a liquid will remain in a tank, theoretically [26, 27].

$$HRT = \frac{V_{\max}}{V_{\max} - V_{\min}} \times \frac{1}{N} \quad (1)$$

Where,

HRT= Hydraulic residence time,

V= storage volume.

The following equation can be used to calculate N or the number of fill/draw cycles every day:

$$N = \frac{24}{\text{Time for (fill /draw) cycle}} \quad (2)$$

This research was conducted to determine how water tanks affect the percentage of organic carbon deposited in the tanks and, consequently, the quality of drinking water. As part of this research, the water tanks located in the departments of the University of Technology in Baghdad were evaluated in 2026, resulting in valuable data and findings regarding tank rehabilitation and maintenance problems. The tank water quality index was also calculated and evaluated, tank types vary from building to building, which may affect organic carbon deposition, bacterial growth and other water parameters.

2. Material and Methods

2.1. Location of the Study

Table 3: Descriptions of study sites

Site NO.	Description
S1 (Ground storage tank entrance)	Taken from the main source of water entering the (UOT). (main pipe)
S2 (Ground storage tank outlet)	Taken from the main reservoir of the (UOT) (a concrete 23 m, and a depth reservoir with dimensions of 13 m, of 9 m) that feeds the tanks of all buildings. (Concrete storage tank)
S3 (Civil Eng. Dept.)	Taken from the water tank of the building of the Department of Civil Engineering, which is 190 m away from the main reservoir. (Fiberglass storage tank)
S4 (Student Activities Dept.)	The reservoir of the student activities building is 240 meters away from the main reservoir. (Steel storage tank)
S5 (Applied Science Dept.)	Taken from the reservoir of the Applied Sciences Building, 230 meters away. (Steel storage tank)
S6 (Laser & Optoelectronics Eng.)	The Laser Engineering Building, with a distance of 510 m. (Nickel storage tank)
S7 (Training & Workshop Center)	The laboratories and workshops were built at a distance of 180 meters from the main reservoir of the (UOT). (Fiberglass storage tank)
S8 (Computer Sciences Dept.)	Taken from the computer science building at a distance of 540 meters. (Steel storage tank)
S9 (Electrical Eng. Dept.)	Taken from the electrical engineering building, which is 580 meters away from the main reservoir. (Fiberglass storage tank)
S10 (Mechanical Eng. Dept.)	Taken from the mechanical engineering building, at a distance of 490 meters from the main reservoir of the university. (Steel storage tank)

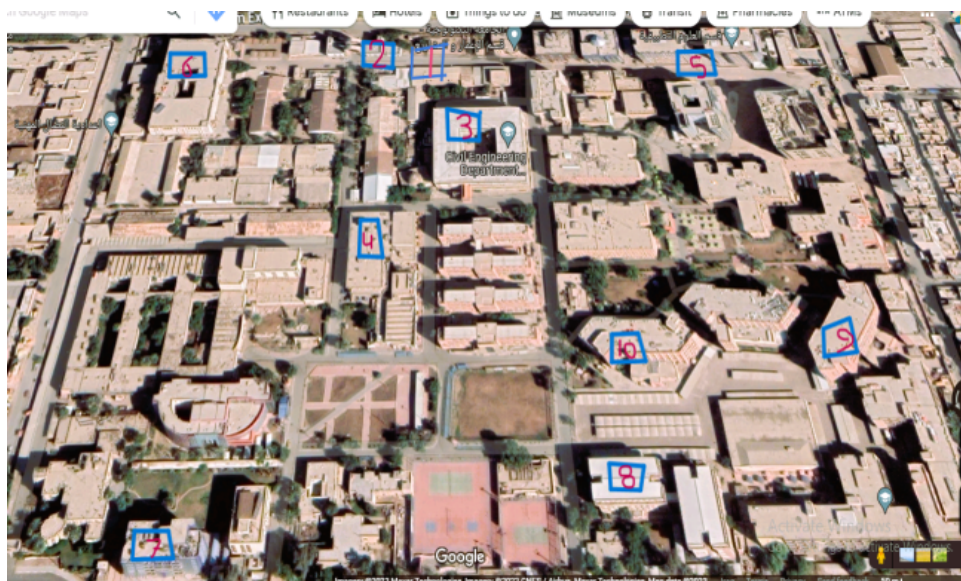


Figure 1: Satellite image for the study area and sampling locations

Water samples were taken from the water tanks at the University of Technology from different points, as well as from the entrance of its main storage tank / Baghdad - Iraq 2026, and other samples were taken after distribution to various buildings (UOT). Figure 1 shows a map of sampling points at the (UOT). Table 3 shows Descriptions of study sites.

2.2. Samples Collection

Sterile, clean polyethylene plastic bottles were used to collect water samples from all storage tanks. Tests were conducted in the Environmental Research Center laboratories. Laboratory tests were performed, and the final results were obtained. All samples were stored in the laboratories under appropriate conditions.

2.3. Chemical, Physical and Biological Parameters

The water parameters measured were (total dissolved solids (TDS), electrical conductivity (EC), Salinity (‰), Magnesium (Mg^{+}), Calcium (Ca^{++}), Total hardness (TH), Turbidity (Tur.), BOD, COD, pH, heavy metals (Cu, Fe, Cd, and Pb) in addition to the (total coliform, *E-coli* test, and total viable count (CFU/mL) Table 4 [28, 29].

Table 4: Lab. measurements according to [28, 29]

Parameter (unit)	Device name and manufacturer	Method number
TDS (mg/L)	Total dissolved solids dried at 180 °C	2540-C
EC (µs/cm)	Portable temperature meter, model H19811 Manufacture Company HANA	2510B
Salinity (‰)	Portable temperature meter, model H19811 Manufacture Company HANA	2520A
Mg^{+} (mg/L)	Titration	Method 3500-Mg B, Calculation Method
Ca^{++} (mg/L)	Titration	Method 3500-Ca B, EDTA Titrimetric Method.
TH (mg/L)	Titration	2340 C. EDTA Titrimetric Method
Tur. (NTU)	Nephelometric method	2130 B
pH	Portable temperature meter, model H19811 Manufacture Company HANA	4500-H+ B
Water temperature (°C)	Portable temperature meter, model H19811 Manufacture Company HANA	2550B
Heavy metals (Cu, Fe, Cd, Pb) (µg/L)	Atomic Absorption Spectrometry, AAS 6300, Shimadzu, Japan	Method 3030 E, Acid Digestion and Analysis By Atomic Absorption Spectrometry
Total coliform test <i>E-coli</i> test Total viable count (CFU/mL)	Multiple Tube Fermentation Technique.	Microbiological application, laboratory manual in general microbiology, Benson 2002.

*NTU: Nephelometric Turbidity Units.

*CFU: Colony Forming units tests.

2.4. Statistical analysis

Descriptive analysis

The acquired data underwent descriptive statistical analysis and one-way analysis of variance (ANOVA) to evaluate the possible significant differences in samples across diverse sampling sites, stations, and sampling months. The statistical significance was determined using probabilities less than 0.05 ($P < 0.05$), and Statistical Release 7 software was employed for this purpose [30].

Correlation matrix

A person's r is widely regarded as the most commonly employed measure of correlation. This is due to the fact that " r " is able to assess the linear correlation between two variables, resulting in its designation as the linear correlation coefficient. As a multivariate analysis technique, it is also one of the oldest methods available [31, 32].

2.5. Results and Discussion

To assess water quality, the main water properties were examined at all sampling points. Table 5 shows the descriptive analysis of the physical and chemical parameters (range, mean, and standard deviation). These results were compared with the Iraqi Drinking Water Standard No. 417 of 2009.

From Table 5, the pH value ranged from 7.4 in (S1) to 7.8 in (S9). The pH was within normal standardized but tended to alkalinity with a mean value (7.77) Figure 2(a). The lowest value of (EC) (861) was recorded in (S2), and the highest was 1174 µs/cm in (S8) Figure 2(b).

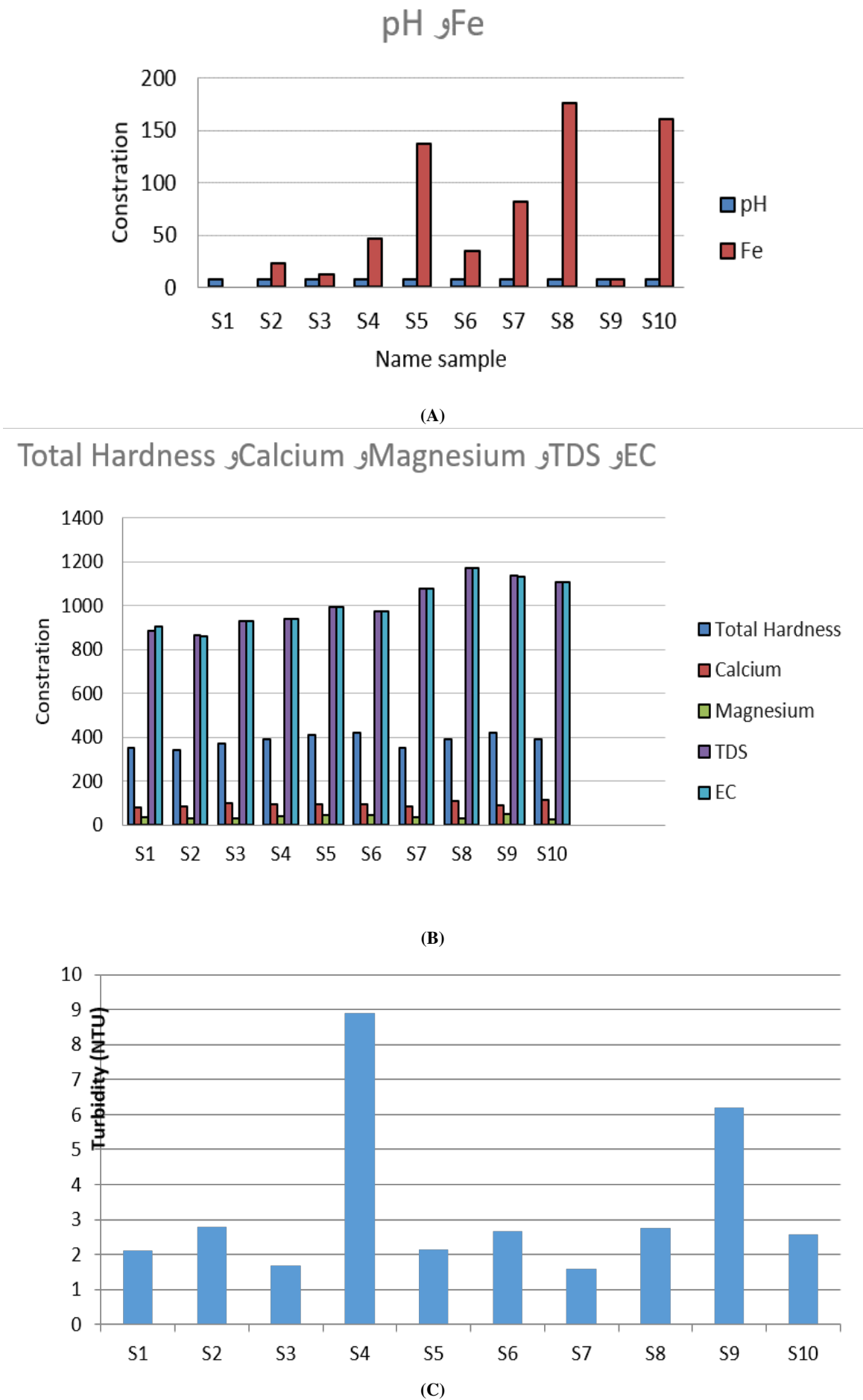


Figure 2: (a, b, c): Physical and chemical parameters of storage tank sampling

The (TDS) ranged from 861 mg/L in (S2) to 1174 mg/L (S8) Figure 2(b). Total hardness (TH) ranged from 340 - 420 mg/L in (S2 – S6 & S9), respectively Figure 2(b), which is within the standard value. The salinity (S ‰) ranged between 0.4 ‰ in (S1 – S6) and 0.5 ‰ in (S7 – S10), which was within the standard value. The results of EC and TDS were recorded for the sites (S8 to S10), showing the highest permissible limits. The minimum value of Turbidity (Tur.) was 1.58 NTU in (S7), and the maximum value was 8.89 NTU in (S4) Figure 2(c). Turbidity was within the acceptable limits except at student activities (S4) and electrical Eng. Dept. (S9), COD test results were also obtained, showing a value of (8 ppm) for the main (concrete) water tank sample and (11 ppm) for the plastic water tanks, indicating the presence of some organic residues in those tanks. BOD testing revealed a value of (0.3 ppm) detected only in the main concrete tank. Tanks at these points need to be cleaned periodically due to the existence of sediments that agitate through tanks filled with water. Ca^{++} ranged from 80.16 (S1) - 112.22 (S10) Figure 2(b). Increasing Ca^{++} concentrations (at all points exceeding 50 mg/L) from the acceptable limit could be attributed to the calcareous layer formed on the inner surface of the old network pipes. This layer may fall and erode continuously, causing an increase in other parameters, not only calcium. In contrast, the Mg^{++} was 26.73 - 48.6 mg/L in (S10 and S9), respectively Figure 2(b), which is within the standard value, Only the Fe from heavy metals (Cd, Cu, and Pb) was detected and ranged between 0 in (S1) to 176.4 µg/L in (S8) Figure 2(a) but was within acceptable limits.

Table 5: Physical-chemical characteristics of water samples

Parameters	Range		Mean	Standard Deviation	Standard values Law 417/2009 (42)
	Minimum	Maximum			
pH	7.4 (S1)	7.8 (S9)	7.77	0.16	6.5-8.5
EC (µs/cm)	861 (S2)	1174 (S8)	1008.5	101.46	1000
S ‰	0.4 (S1-S6)	0.5 (S7-S10)	0.44	0.07	0.8
TDS (mg/l)	861 (S2)	1174 (S8)	1006.6	101.4	1000
Tur. (NTU)	1.58 (S7)	8.89 (S4)	4.89	2.69	5
TH (mg/L)	340 (S2)	420 (S6 & S9)	383	27.94	500
Ca^{++} (mg/L)	80.16 (S1)	112.22 (S10)	93.79	9.59	50
Mg^{++} (Mg/L)	26.73 (S10)	48.6 (S9)	36.21	6.99	50
Cd (µg/L)	0	0	0	-	3
Cu (µg/L)	0	0	0	-	1000
Fe (µg/L)	0 (S1)	176.4 (S8)	68.18	52.13	300
Pb (µg/L)	0	0	0	-	10

*(-): not applicable or available.

Table 6 represents bacterial growth at sampling points in accordance with the storage tank type. Total coliform and E.coli tests were positive at the main supply pipe (S1) and concrete storage tank (S2). The total viable count was about 4 CFU/100 mL at the main entrance (S1), exceeding the permissible 1 CFU/mL limit Figure 3. Bacterial growth values were not dependent on the storage tank type, as was expected that fiberglass tanks were considered a suitable environment for bacterial growth. However, the main effecting factors were the maintenance and periodic cleaning of the tanks [33]. Bacteria may contaminate water with human and animal excrement. Water that has been tainted by feces carries dangerous microorganisms, making it unsafe to use in daily activities for humans [34]. Additionally, the high bacterial count was caused by outdated piped city projects or an ineffective filtering and precipitation process; the sterilizing process's chlorination duration was insufficient [35].

Table 6: Results of bacteriological investigation of drinking water samples

Sample No.	Coliform test (CFU/100 mL)	E. coli. Test (CFU/100 mL)	Total viable count (CFU/100 mL)
S1	4	+	+
S2	0.7	+	+
S3	0	-	-
S4	0	-	-
S5	0.2	-	-
S6	0	-	-
S7	0	-	-
S8	0.2	-	-
S9	0.7	-	-
S10	0.2	-	-

*(+): contain coliform bacteria over normal count.

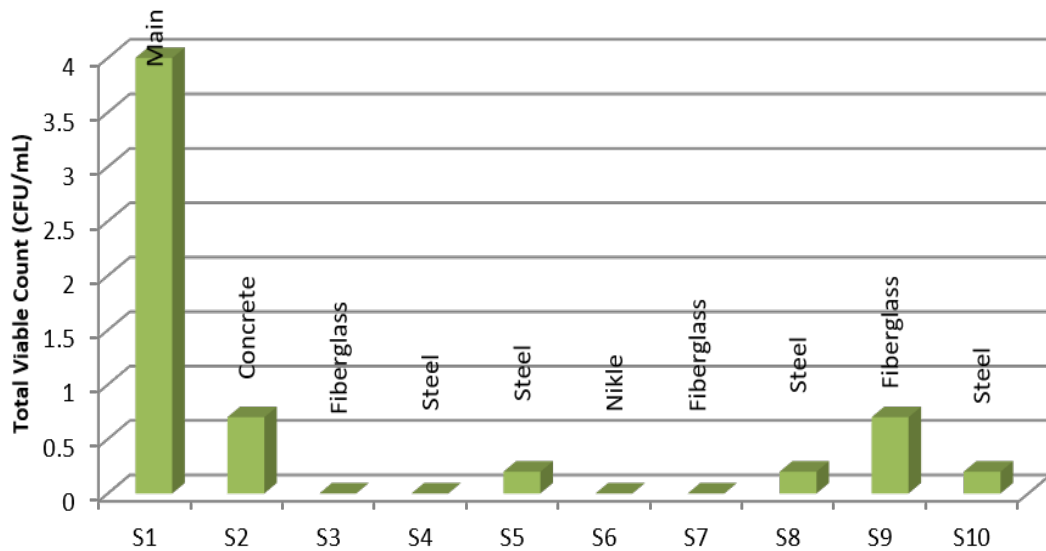


Figure 3: Total viable count values at different points of storage tank sampling

Significant positive, strong correlations ($P < 0.05$) were observed between EC-Sal. ($r = 0.9176$), EC-TDS ($r = 0.9986$) and Sal.-TDS ($r = 0.9139$) Table 7 during the study period [36]. This means that increasing EC values is directly related to the presence of TDS and Salinity in the water sample; in addition to the relation between Salinity and TDS, increasing Salinity directly affects the values of TDS in the water sample.

Table 7: Person's correlation coefficient of physical-chemical parameters of water samples

Parameters	Fe ($\mu\text{g/L}$)	pH	EC ($\mu\text{s/cm}$)	Sal. (%)	TDS (mg/L)	Tur. (NTU)	TH (mg/L)	Ca ⁺ (mg/L)	Mg ⁺⁺ (mg/L)
Fe ($\mu\text{g/L}$)	1.000								
pH	0.4655	1.000							
EC ($\mu\text{s/cm}$)	0.6285	0.6536	1.000						
Sal. (%)	0.4973	0.5533	0.9176*	1.000					
TDS (mg/L)	0.6298	0.6908	0.9986*	0.9139*	1.000				
Tur. (NTU)	-0.2190	0.2543	0.0233	-0.0224	0.0362	1.000			
TH (mg/L)	0.2315	0.5559	0.4517	0.1315	0.4655	0.3549	1.000		
Ca ⁺ (mg/L)	0.6792	0.4918	0.5148	0.3597	0.5234	-0.0847	0.4125	1.000	
Mg ⁺⁺ (mg/L)	-0.3646	0.1129	-0.0080	-0.1843	-0.0022	0.4179	0.6127	-0.4672	1.000

* $r \leq 0.3$ = weak correlation; r between 0.5 and 0.7 = moderate correlation; $r > 0.7$ = strong correlation (50).

Calculation of the water quality index at sampling points was done Table 8. This was introduced by computing the water quality index WQI [37], as shown in Table 8. According to the WQI classification shown in Tables 5, water quality could be classified as good water, with differences in quality depending on the maintenance and periodic cleaning of tanks, as illustrated previously. Figure 4 shows WQI in relation to distances between the water sampling points. From the figure, it appears that water quality worsens at the endpoint of sampling. This could be expected due to the old network pipe, which needs to be maintained in addition to the storage tanks to keep excellent water quality. Finally, it is essential to mention that increasing turbidity values affect adversely the residual chlorine concentration, and this, in turn, maybe a reason for increasing bacterial growth in tanks and pipes at the distribution system [38].

Table 8: Water Quality Index at Sampling Points

Sample No.	Sampling Point	WQI Value	Water Quality
S1	Ground Storage tank entrance	54.6188	Good water
S2	Ground Storage tank outlet	56.6030	Good water
S3	Civil Eng. Dept.	54.3084	Good water
S4	Student Activities Dept.	72.1179	Good water
S5	Applied Science Dept.	55.7173	Good water
S6	Laser & Optoelectronics Eng. Dept.	57.0462	Good water
S7	Training & Workshop Centre	63.5497	Good water
S8	Computer Sciences Dept.	66.9570	Good water
S9	Electrical Eng. Dept.	75.3337	Good water
S10	Mechanical Eng. Dept.	66.5678	Good water

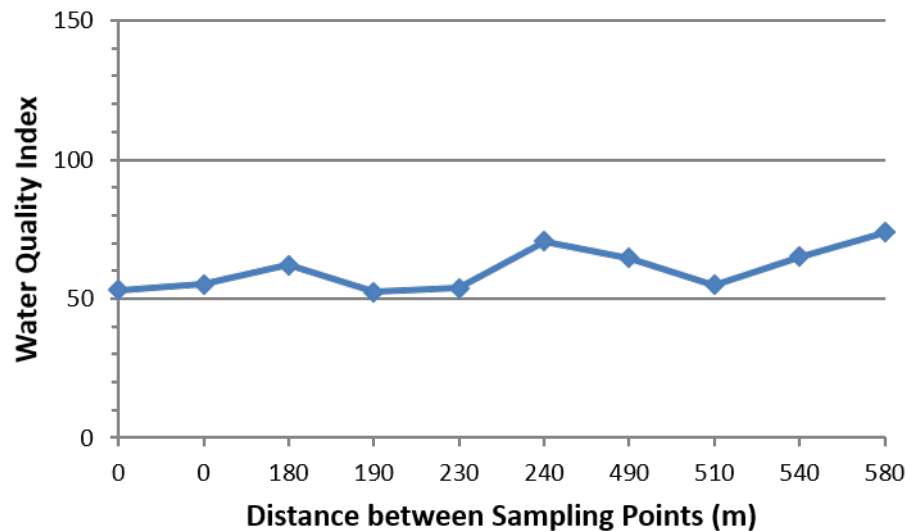


Figure 4: Water quality at different distances of sampling points

3. Conclusions

According to the obtained results, the following conclusions can be drawn:

- Physical and chemical water parameters were within the acceptable limit. Magnesium, EC, and TDS increased at some points, especially at the end of line sampling. This could be attributed to the pipes' calcination, which may continuously fall and abrasion, in addition to the sediments in storage tanks.
- Cd, Cu, and Pb concentrations were not found, and Fe concentrations were within limits.
- Total coliform and E.coli tests were positive at the main supply pipe and main concrete storage tank. The total viable count was about 4 (CFU/100 mL) at the main entrance, which exceeded the permissible limit. This indicates the need for the maintenance and periodic cleaning of the primary storage tank.
- Water could be classified as good water quality.

Article Information

Data Availability: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of Interest: The authors declare that they have no conflict of interest.

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