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EVALUATION OF AL KABEER AL SHAMALI RIVER'S WATER SUITABILITY FOR DRINKING, BASED ON MODELLING AND PSEUDOMONAS AERUGINOSA DETECTION. SYRIA

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Abstract: Using Al Kabeer Al Shamali River water as a source of drinking water is a big bacteriological challenge. So, the aim of this study was to determine Ps. aeruginosa bacteria and its correlation with drinking water quality and heterotrophic bacteria HPC in three locations; lake inlet " Ghammam Bridge ", artificial (the 16th Tishreen Dam Lake, and lake outlet Ain al-Bayda irrigation tunnel). during the period 2018-2019 and 2019-2020. membrane filtration technique was used to detect Ps. Aeruginosa. Results showed significant differences ($p<0.05$) between sites for Ps. Aeruginosa, EC, Tur and NO_3^- . The highest counts for Ps. aeruginosa were recorded in Ghammam Bridge water reaching 290000 cfu/100 mL in Jun and correlated with NH_4^+ ($r = 0.72$). Then counts decreased to 420 cfu/100 ml in May in 16 Tishreen Dam Lake water, due to stratification and environmental stresses. Ps. Aeruginosa counts were higher in lake outlet than 16th Dam Lake and reached 53000 cfu/ 100 ml May due to the release from sediments. Ps. Aeruginosa. correlate with HPC bacteria and NH_4^+. That's mean Bacteria play a role in treating polluted water. Canadian Water Quality Index CCME WQI showed that the lake inlet water is moderate class C (64). The waters of 16th Dam Lake and the outlet are of good grade II B due to sedimentation. These results provide the basis for choosing appropriate sterilization methods to reach health goals to connect this major water source to the drinking water network in Lattakia city.

Keywords: Pseudomonas Aeruginosa, CCME WQI, Drinking Water, Al Kabeer Al Shamali River.

1. Introduction

According to the World Health Organization half of the world's population will live in water-stressed areas by 2025 and climate change will lead to greater fluctuations in rainfall [1]. Sustainable Development Goal target 6.1 calls for universal and equitable access to safe and affordable drinking water. The target is tracked with the indicator of "safely managed drinking water services" – drinking water from an improved water source that is located on premises, available when needed, and free from faecal and priority chemical contamination. In 2020, 5.8 billion people used safely managed drinking-water services – that is, they used improved water sources located on premises, available when needed, and free from contamination. The remaining 2 billion people without safely managed services in 2020 of which 733 million live in high and critically water-stressed countries [2], [3]. Rapid economic growth, a growing population, rising standards for living, climate change, increasing water scarcity, and demographic changes have increased the demand for fresh water. All are challenges for drinking water supply systems. Integrated management of water resources will need to be improved to ensure availability and quality. Recently, developing countries have faced significant problems in protecting water quality when trying to improve water supply and sanitation even developed countries were struggling to maintain or improve their water quality status in the face of eutrophication problems [4], [5]. Microbiologically contaminated drinking water can transmit diseases such as diarrhoea, cholera, dysentery, typhoid and is estimated to cause 485 000 diarrhoeal deaths each year [1].

The catchment of Al Kabeer Al Shamali River has been a place of intensive economic transformation since the 1985 when 16 Tishreen Dam Lake was built for irrigation purposes. Because of high annual population growth rate of the River basin 2.1% [6], [7]; it is necessary to study the water quality of 16 Tishreen Dam Lake as a source for drinking water.

Previous study in Al- jenderia site [8], [9] investigated some physico–chemical, bacteriological parameters, and some heavy metals in the water of Alkabeer Alshamali River and two neighboring wells in the period 2008-2009. The results were within the allowed limits according to national and international standards [9]–[12] except for the river which had higher physico–chemical, bacteriological pollutants. This may suggest that soil and sediment filtered most of these pollutants before they entered the groundwater.

In current study, we will research the upper river where Water reservoirs can be divided into natural waters (Al Kabeer Al Shamali River "Ghammam Bridge site" which is donation reservoir to artificial (16 Tishreen Dam Lake, and the outlet Ain al-Bayda irrigation tunnel).

previous study [11] focused on hydrochemical characteristics of Al Kabeer Al Shamali River water and concluded that Piper diagram showed that hydrochemical characteristics of the water inlet was belong to the type of Ca–HCO3, and the lake and outlet altered from Ca–HCO3 to Mg-HCO3 type. saturation index (SI) indicated that carbonate minerals (dolomite, calcite and aragonite) were supersaturated (SI>0), while gypsum and halite were unsaturated (SI<0). Thus, the water can dissolve more gypsum and increase the SO42− concentration until it reaches a degree of saturation.

The effect of diverting water from the Al-Kabeer Al-Shamali River on the fate of faecal microbial indicators were discussed very well in previous study [13]. by the indicators of the faecal microorganism Thermotolerant Coliform bacteria (TTC) (common name Fecal coliform) where in most cases monitoring of E. coli or TTC gives high accuracy due to its presence in large numbers in polluted water.

Source of Microorganism in water bodies may be from humans and hot-blooded animals [14], may enter rivers either directly or indirectly, and are exposed to environmental stresses causing a decrease in their numbers in aquatic environments [15].

In current study, we will focus on Pseudomonas. Aeruginosa "opportunistic water born diesis". Which may enter water bodies in a variety of direct or indirect ways. Pseudomonas is common bacteria that could be found in soil and water [16]. It is one of the more common causes of healthcare-associated infections and is increasingly resistant to many antibiotics. Common infections include pneumonia, urinary tract infections, septicemia and gastrointestinal infection. In hospitals, the bacteria can contaminate moist or wet reservoirs such as respiratory equipment and indwelling catheters [17].

Stagnant water may give Pseudomonas bacteria the perfect conditions to grow and multiply. This can lead to biofilm formation and other problems such as corrosion. The biofilm can form on the pipe and heat exchanger surfaces, causing a reduction in the efficiency of the system [17]. It was not mentioned in The Syrian Arab Organization for Standardization & Metrology [4] but mentioned in some international [18] with zero CFU / 100 ml limit for potable water so we will discuss it in the water source before use for drinking especially when use Stagnant water "16th Tishreen dam lake" with relatively high organic carbon NPOC concentrations which approved in previous study [19].

Water quality assessed by biological, physical and chemical indicators. Several health-based limits and mandatory drinking water standards exist in national [4] and international [4], [11], [20] [3], [21] [22] [23] [18] standards.

Water quality management requires the collection and analysis of a large dataset on water quality that is difficult to assess and synthesize. Therefore, a set of tools has been developed to assess water quality. Its objective is to assess the quality of drinking water by calculating the Water Quality Index (WQI), which is an important tool for determining whether water is suitable for individual consumption or not. The WQI has been widely used since the 1960s [24] for its ability to fully utilize variable water quality information and to assess the overall state of water quality through a clear standardized value in a single term [25], which helps in choosing the appropriate treatment technology to meet the problems in water treatment plants. On the other hand, it interprets the compounding effect of water quality standards and communicates water quality information to the public and legislative decision makers. The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) has been developed by the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI). [26], which was used commonly to assess river water quality.

The objectives of the research: There is a great lack of information on the possibility of benefiting from the waters of dam lakes and irrigation tunnels as sources of drinking water. Hence the need to evaluate the microbial content of water sources before using them as sources for drinking water. Therefore, the objectives of the current study are to assess water quality:

1. Classification of water quality by CCME water quality index by studying some physicochemical changes such as temperature (T Cº), pH, dissolved oxygen (DO) and nutrients Nitrate $NO3^-$, Nitrite $NO2^-$, Ammonia $NH4^+$, Phosphate $PO4^{-3}$. Thermotolerant Coliform bacteria (TTC)
2. Detection of some spatial and temporal changes of Ps. Aeruginosa bacteria counts in the waters of the inlet of the lake "Ghamam bridge", Lake 16th Tishreen Dam lake, and Ain Al-Bayda irrigation tunnel.
3. Correlations between Ps. Aeruginosa and heterotrophic bacteria HPC.

2. Materials and Methods

Study Area: Three locations were studied the natural water lake inlet " Ghammam Bridge site ", artificial (the 16 Tishreen Dam Lake, and the outlet Ain al-Bayda irrigation tunnel).

Al Kabeer Al Shamali River: The River is considered one of the most important, largest and longest coastal rivers. Its source from the Iskenderun at an altitude exceeding 1100 m. The lands of the river basin of the Al Kabeer Al Shamali River are distributed among three governorates (Lattakia, Idlib and Hama), the largest part of which is within the Lattakia governorate (Fig. 1).

The river is characterized by a high flow during the winter and spring seasons. This flow was estimated at 189.5 million m3 annually, with an average of 6.78 m3/s at Ghamam Bridge site (Fig. 2). Its flow reaches 40 m3/s during the flood season, and it almost dries up in the summer, which prompted the state to construct the 16th Tishreen Dam lake. It flows quickly and narrowly to the dam area and then turns into a plain river, the width of its reaches 600 m. The climate in the region is the Mediterranean, where the weather is mild and humid in winter and mild to hot and humid in summer, and the temperature rarely drops below zero in winter and does not exceed 35 C° in summer. The study area is also characterized by relatively high values of humidity ranging between 60-76%. Increasing the relative humidity reduces the intensity of evaporation and helps surface runoff. The winds are northeasterly and easterly in the period (from October to May), and southerly southwesterly in the hot season. As for the rainfall, it is relatively high, ranging between (800-1200) mm annually. Most of it (50-60%) falls between the months of December to February, and a little of it falls during the months of October, November, March and April. It is rare for precipitation to occur in summer months [27].

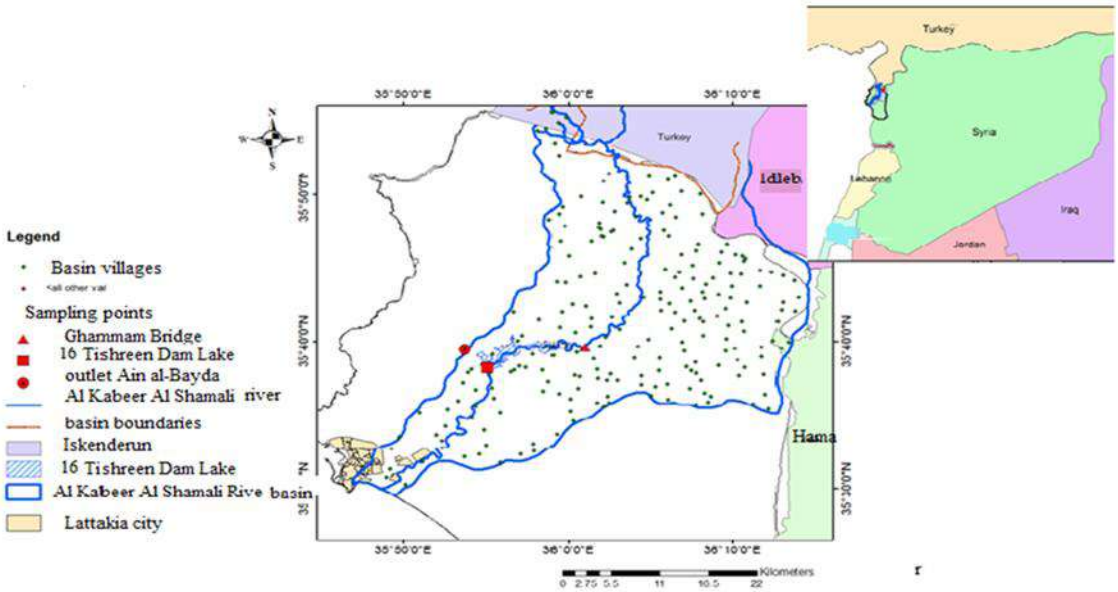


Figure 1. A map of the population centers within the Al Kabeer Al Shamali River Basin.

Figure 2. The site of Ghamam Bridge (lake inlet) is characterized by a narrow, sloping, and fast flowing stream with turbid water sight.

16 Tishreen Dam Lake: Its area is estimated at 11.2 km2, with a maximum storage capacity of 212 million m3. The length of the dam body is 1 km at the top, and its height is 53 meter. The natural storage level above sea level is 74.60 meters. It is located 15-17 km east of Lattakia city, near the village of Qsmin. It is an earthen dam built on the Al Kabeer Al Shamali River since 1985, it is equipped with a spillway that allows the flood water to be disposed of and converted into valley below a dam when the water level in the lake reaches a certain limit. The shape of the lake depended on the geographical location, with a thick sediment layer of sand and gravel. It is bordered by mountains and plateaus to the west and east. The volume of water stored within the dam lake is also characterized by significant seasonal changes in winter and spring. Storage dams are stored in winter and spring and emptied in summer and early autumn for agricultural irrigation, where the greatest capacity is in the months of February, March and April, and the lowest in September and October [27]. Storage dams differ in measuring their shape, so they are lakes. Natural reservoirs are more circular while reservoirs are long and narrow with complex banks. In addition, residence times are shorter in reservoirs than in lakes (almost half their length) [28] (Fig. 3).

Figure 3. 16 Tishreen Dam Lake (clear sight).

Ain al-Bayda Irrigation Tunnel: it emerges from the 16th Tishreen Dam Lake, at a height of 57 meters above sea level, with an average abundance of 4.5 m3/s, which varies according to irrigation requirements. Its long about 7.2 km from a drinking water purification plant where will be established [27] (Fig. 4). There are many industries located on the banks of Al Kabeer Al Shamali River, in addition to agricultural and mining activities, including: Factories (battery plant) and the water is poured directly into the river through a sewer, Al-Zoubar Marble Factory, Barakat Marble Company, Kafriya Asphalt Plant, and Olive press, about 13 presses: their water are drained into the riverbed.

Current study focuses on the upper part of the river inlet "Ghamam Bridge", 16th Tishreen Dam Lake, and Ain Al-Bayda irrigation tunnel where a drinking water treatment plant will be established (Fig. 5).

Figure 4. Ain al-Bayda irrigation tunnel (lake outlet) The water is clear and transparent.

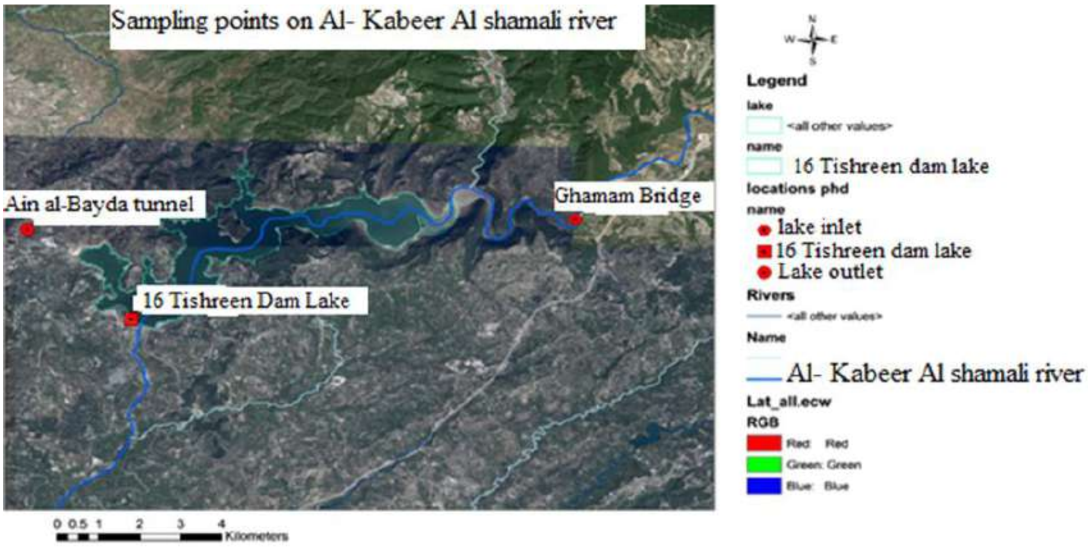


Figure 5. A satellite image of Al- Kabeer Al shamali river, 16 Tishreen Dam Lake, and Ain al-Bayda irrigation tunnel (Arcmap 10.5 program).

Sample Collection Methods: Samples were collected in the period 2018-2019 and 2019-2020 from the upper water layer of the lake and river 25 cm^{-1} meter. River samples were taken from the Ghamam Bridge site, in the middle of the river where the flow is, and the bottles were immersed below the surface of the river, against the direction of the flow (Fig. 2). As for the dam samples, they were taken near the funnel of the secondary spillway. Samples were taken from Ain al-Bayda irrigation tunnel from its exit (Fig. 4). The frequency of tunnel samples varied according to the irrigation season, from May to October.

Bacterial analysis samples: 500 ml glass containers were used, well washed and sterilized in autoclaves, and placed in a special refrigerated bag. The required analyses were carried out soon in the laboratory. The temperature and dissolved oxygen were measured in the field using the Dissolved Oxygen Meter.

Physiochemical samples: They were collected in bottles made of polyethylene with a capacity of one liter, which were well washed and dried.

Bacteriological analyses: membrane filtration procedure was used to determine Ps. aeruginosa bacteria. An appropriate volume of the sample was filtered through a membrane with a pore size of 0.45 mm. The membrane was incubated on selective media, and appropriate temperatures. (Table 1), then the colonies were counted and the results were recorded as one colony formation (CFU). Standard spread plate count method was used to examine heterotrophic HPC according to national standard methods [29].

Table 1. The studied bacterial groups, selective media, and appropriate temperatures according to [29].

Bacteria	Reagent Media	Degree of incubation and duration time	The shape and color of the colonies
HPC	Plate Count Agar	37 C° for 24- 48 h	**Selectively aerobic anaerobic**
TTC	M-FC agar	44.5 C° for 24 h	**Blue colonies with a metallic luster due to fermentation of the sugar lactose**
Ps. aeruginosa	Cetrimide Agar	37 C° for 48-72 h	**Colonies are obligatory aerial colonies, smooth, round, 0.8-2.2 mm in diameter, flat, light-colored, with blackish-greenish or brown centers. Distinctive, grape-like smell.**

Physical measurements: The approved methods were followed in the analyzes [29], including turbidity, and the results were recorded in an estimate of (NTU) Nephelometric Turbity Units, Electrical Conductivity, Total Dissolved Solids and pH (Table 2) (fig. 7).

Chemical measurements: Spectrophotometer HACH DR 2010 was used to measure the ions of Nitrate NO3, Nitrite NO^{2-}, Ammonia NH4+, and Phosphate $PO4^{-3}$, in mg. L^{-1} [29].

Table 2. Laboratory methods used in measuring physiochemical parameters [29].

Parameters	Symbol	Units	Analytical Method/Standard	Instruments
Potential of hydrogen	PH	-	pH meter	Orion 410 A
Dissolved oxygen	DO	mg. L^{1-}	Dissolved oxygen meter	YK 22 DO
Turbidity	Turb	NTU	Turbidity meter	Turbidity meter 2100
Electrical conductivity	EC	µS/cm	Electrical conductivity meter	Thermo Orion 115
Total Dissolved Solids	TDS	mg. L^{1-}	Total Dissolved Solids *meter*	Thermo Orion 115

Software used:

- ArcGis (Arcmap) software (10.5, Esri, USA) was used to determine the sampling sites, map the effluents of the studied sites.

- Excel (Microsoft, USA 2013 version) for statistical analysis and One Way-ANOVA at the significance level 0.05 for the original data. Pearson correlation analysis to find the relationship between water quality parameters.

3. Results and Discussion

physiochemical measurements: Temperature: Intestinal bacteria (pathogens and non-pathogenic alike) are mesophilic, within the range of 20 C°-40 C°. The temperatures in the current study ranged between 13.8 C° in the waters of Lake Inlet, Ghamam bridge and lake in February, and reached 32.5 C° in the tunnel waters in July, followed by 31.9 C° in the lake waters. As for the tunnel water, no temperature was recorded in the winter due to the lack of pumping into tunnel, and the lowest recorded temperature was 21 C° in May, with the start of the irrigation season. Studies indicate [30], [31] that the more as the temperature rises, the ratio of carbon to nitrogen (C: N) in surface water increases due to the decomposition of organic matter these approved by our Previous research by [19] showed an increase in the ratio of C: N in the samples of the months of July and September in lake water 23, 22.5, respectively. Along with temperatures of 31.5 and 28.9 C°for the year 2019, respectively, due to the decomposition of plant residues by the existing bacteria, and this is what we will notice later in pseudomonas counts.

Dissolved Oxygen: The lowest DO value was recorded in October, 5.5 mg. L-1, in the lake inlet water, as shown in (Fig. 8). In addition, a low value was recorded in the waters of the dam lake, 5.5 mg. L-1, in September, as high counts of bacteria cause depletion of oxygen from the medium directly due to the decomposition of organic matter. It was found through previous research, [8]that the counts of (HPC) bacteria recorded relatively high counts in the waters of the dam lake during the months of September and October were associated with a decrease in DO and an increase in the C/N ratios. In addition, the concentration of DO decreased in September to 6.7 mg. L-1 in the tunnel water [32]. The high water temperature stimulates the enzymatic activity of microbes to multiply strongly during this season. This is what we will observe in details next for Ps. aeruginosa.

On the other hand, the concentration of DO increased to 12 mg. L-1 in winter in January and February with lower temperatures. It is important to note the inverse correlation between temperature and dissolved oxygen at all sites (Fig.6) and that was discussed in [22].

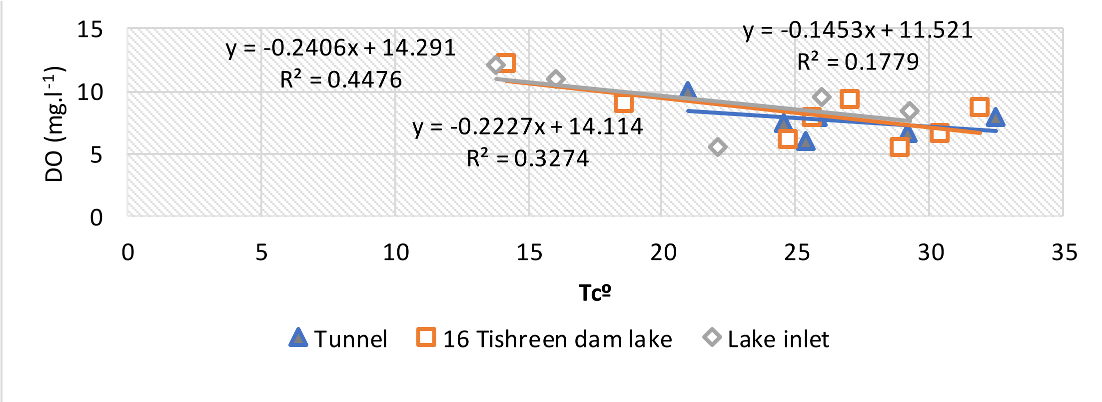


Figure 6. A Scatter plot shows Negative correlation between C°and DO in Al Kabeer Al Shamali River water.

Dissolved oxygen device **Phosphate measure** **Electrical conductivity**

Figure. 7. Some instruments used.

pH: The highest average pH was recorded in the lake entrance water 8.04, followed by the dam lake 7.92, then the tunnel 7.92. The highest value was recorded in the river water, 8.13, in July, and the lowest value was recorded in the water of the Ain al-Bayda irrigation tunnel, 7.41, in April. The results show that the nature of the water is weakly alkaline and meet limits for drinking water [4].

Nitrate: An ANOVA analysis of variance confirms the presence of significant differences between the studied sites. The highest concentration was recorded in the lake inlet water and reached 4 mg. L^{-1}in December. It is a lower value than the value recorded in the waters of Al-Kabeer Al-Shamali River at the site of the wells of Al-jenderia 8 mg. L^{-1} [8], [9]. Followed by the tunnel, and the highest value was recorded in April, 2.9 mg. L^{-1}. Easily soluble nitrate quickly enters surface and groundwater. The concentration of nitrogenous ions changed according to the seasons. The concentrations of nitrate were associated with the amount of dissolved oxygen in the water, so the values increased in winter-spring in the three locations (Fig. 8). The oxidation state may cause a nitrification reaction that usually converts ammonia (NH_4^+) into nitrate (NO_3^-), thus it also increases the nitrate concentration in surface water. According to studies [33]. The process of nitrification reaches its maximum activity in the spring. The concentration of nitrates decreased in the lake water and with average of 1.19 mg. L^{-1} was recorded due to anaerobic conditions with increasing water depth [34]. So Disposal of organic and nitrogenous materials in water bioremediation, especially in anaerobic conditions.

Change of NO_3^- concentration from rainy season until summer due to physical, chemical and biological processes (such as nitrification and/or denitrification). It decreased in summer due to rapid growth of algae in the river which consume N-NO_3^- as their substrate.

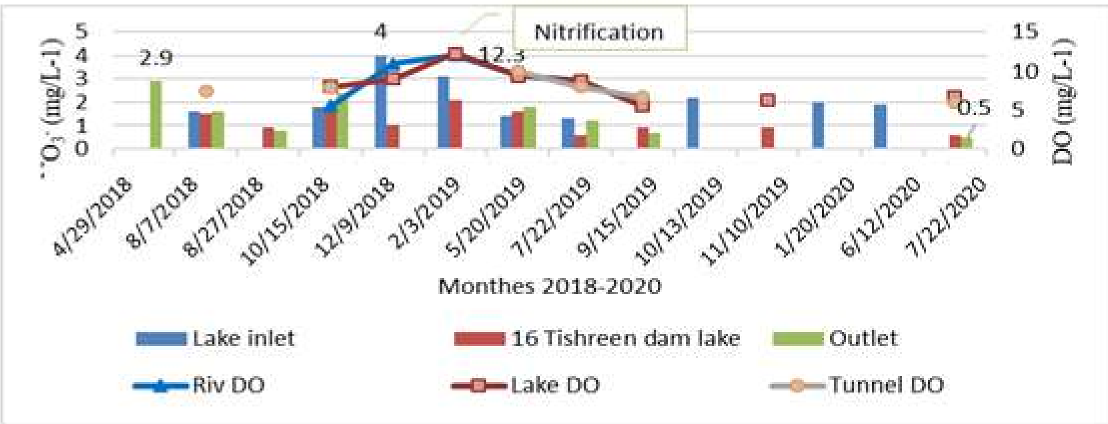


Figure 8. Changes of NO_3^- and DO in the waters of the studied sites on Al Kabeer Al Shamali River.

Nitrite: The highest concentration of nitrite recorded in the waters of the 16th Tishreen dam lake and reached 0.039 mg. L^{-1} in July. The accumulation of nitrite indicates a denitrification process. This confirmed with a decrease in nitrate concentration and an increase in ammonia concentration at the same time (July). ". The lowest concentration recorded in the inlet water 0.001 mg. L^{-1} in February (Fig.9).

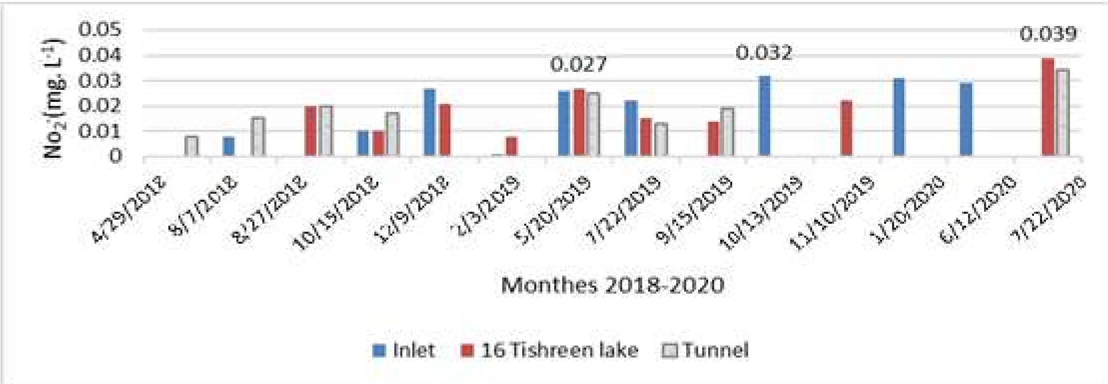


Figure 9. Changes of NO_2^- concentrations in the waters of selected sites on Al-Kabeer Al-Shamali River.

Ammonia: The highest concentration was recorded in the lake's inlet water, reaching 0.2 mg. L^{-1} in June, which is a lower value than the value recorded in the waters of Al-Kabeer Al-Shamali river at the site of the Al-jenderia wells, 0.24 mg. L^{-1} [8], [9]. The highest concentration was recorded in the outlet water 0.13 mg. L^{-1} in August with increase in temperature. The lowest concentration was recorded in of 16 Tishreen dam lake waters and lake outlet in the spring (0.01, 0.02 mg. L^{-1}), respectively, where the environmental conditions are suitable for the growth and reproduction of nitrifying bacteria in terms of the abundance of dissolved oxygen in the medium (Fig. 10). The study [35] indicated that the peak of algae growth in May, June and early July, and indicates nitrogen metabolism through nitrite/nitrate reduction by cyanobacteria in early summer and during trophic conditions.

Nitrogenous ions were recorded in the three studied sites, in the following order: $NO_3^- > NH_4^+ > NO_2^-$. It is the same arrangement at the site of the wells of Al-jenderia [8], [9]. We will show later the correlation between NH_4^+ and *pseudomonas* counts. A previous study [8], [9] showed the presence of a strong correlation coefficient (r = 0.71) between NH_4^+ and total coliform bacteria (TC) in Al-Kabir Al-Shamali River waters at the site of Al-jenderia wells, an indication that the source of the ammonium ion in the river water is the throwing of untreated human waste into the river stream because the ion is The ammonium indicates that the contamination is recent and that the self-purification process is well.

The higher concentration of NO_3^- than NH_4^+ in water in general can be explained by the fact that the ammonium ion is dissolved in the solution or adsorbed on the surfaces of the adsorption complex, in contrast to the nitrate ions that remain free in the soil solution and thus are washed into the water.

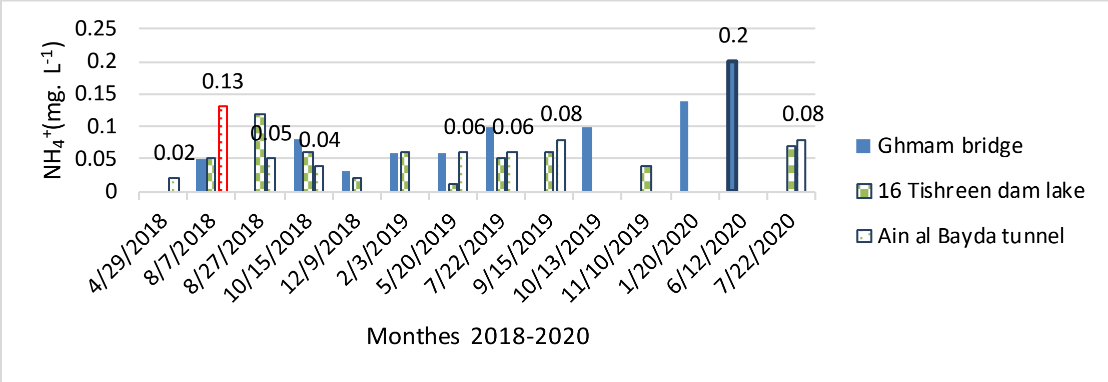


Figure 10. Monthly changes of NH_4^+ concentrations in the water of the studied sites.

Phosphate (dissolved reactive Phosphor P (MRP): The highest concentration recorded in the lake inlet water 0.45 mg. L^{-1} in January after heavy rains. The highest concentration was recorded in the waters of the dam lake and the lake outlet in July (0.41, 0.45 mg. L^{-1}), respectively (Fig. 11). In the study [33] noticed the effect of these concentrations on the calcite saturation it could be via *pseudomonas* activity.

The lowest concentrations were recorded in May and were in the lake inlet water 0.09 mg. L^{-1} and in the lake and outlet water 0.05 mg. L^{-1}.

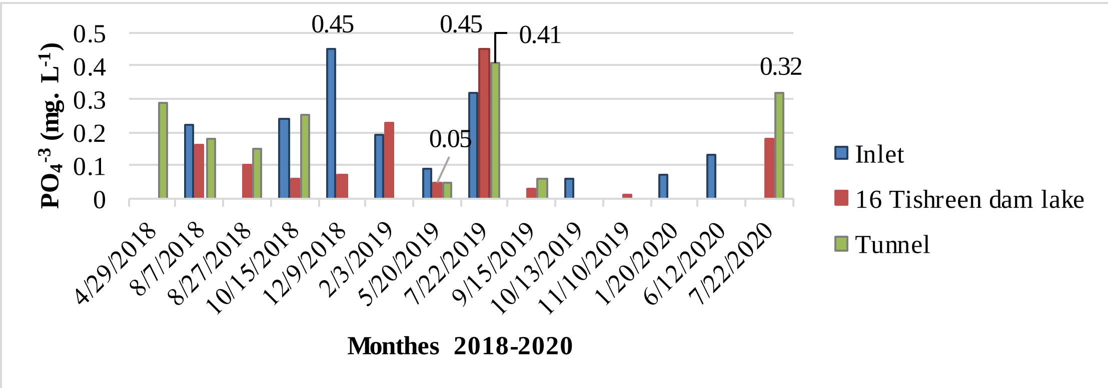


Figure 11. Monthly changes of PO_4^{-3} in the water of the studied sites on the Kabeer Al-Shamali River.

It was evident in the current study, where the concentration of phosphate increased in the three sites in July. Phosphate inhibits the precipitation of $CaCO_3$, and causes supersaturation of calcite in the surface water layer, which occurs in the spring [30], [36]. This noted by the high calcification in July along with the high phosphate, and this confirmed by the high calcite saturation coefficient in July, as we discussed in previous study [33]. Studies refer to *Pseudomonas aeruginosa* in this process.

A significant increase in storm flow dissolved reactive P (MRP) concentration with storm events and recorded high values 0.45 mg L^{-1} in December in inlet water. It is as like as in previous study [8] when recorded 0.36 mg L^{-1} for well 2 in winter. That suggests that P release from soil and/or area of the watershed producing runoff increase with storm size [37].

Pseudomonas aeruginosa changes:

Ghmam bridge (lake inlet) site: The highest counts were recorded in the lake inlet water 290000 CFU/100 mL in June, during the summer civil activities, and two high peaks in the winter, when counts reached 200000

CFU/100 mL in February, after heavy rains, and the resulting erosion from the neighboring lands, where *Pseudomonas* is one of the most important soil bacteria. A high count was also recorded in the fall, when the plant residues decomposed, and the accompanying high *Pseudomonas*, so it was recorded in October 2019, a count of 70,000 CFU/100 mL (Fig. 12). The lowest count was recorded in May, 10000 CFU/100 mL, associated with a decrease in turbidity to the lowest value of 1.52 NTU.

In previous study [8] in Alkabeer Alshamali River water in the highest value was recorded in the river in November (170000 cells/100 ml) associated with high turbidity (10 NTU) and throwing olive press waste directly into the river. The presence of *Ps. aeruginosa* indicates that the self-purification process is proceeding well. *Ps. aeruginosa* is used in the biological treatment of phenols present in the olive mills stream, where it decomposes them.

Ps. aeruginosa has the same trend for HPC bacteria in our research. The standard plate count agar procedure was used for analyzing samples for HPC bacteria [3]. The highest count was recorded in inlet water and reached for 4000 CFU/mL in October. HPC showed a strong correlation coefficient with NH_4^+ (r =0.71) Then decreased in the water of the dam lake because of stratification, and sunlight effect with a linear correlation with turbidity (r =0.87). Then increased again in the tunnel to 650 cfu/mL on July because release of sediments with respect to PO_4^{-3} relationship with HPC (r =0.91). Therefore, we could predict *Ps. aeruginosa* counts from HPC bacteria.

16th Tishreen Dam Lake site: The *Pseudomonas aeruginosa* counts decreased in the 16 Tishreen dam lake water to the low values of 1000 cfu/100 mL in August due to the stratification of the lake and the redistribution of *Pseudomonas* between the surface and deep layers of the lake water and then its release again from the sediments in the deep and dark waters that stimulate the growth of bacteria, as we will notice in the tunnel water. The highest values were recorded in the lake water in autumn, as the counts increased to 19000 cfu/100 mL in October 2019 with a turbidity rise of 13.2 NTU, and the counts recorded in October 13000 cfu/100 mL associated with a turbidity of 3.88 NTU, a decrease in the lake level and decomposition of plant residues, causing an increase in the C/N ratio [31]. On the other hand, the lowest concentration of 420 cfu/100mL recorded in the lake water in May 2019, associated with a relatively low turbidity of 2.27 NTU and the lowest pH value of 7.75.

Ain al-Bayda irrigation tunnel: recorded higher *Ps. Aeruginosa* counts than dam lake water during the study period, and the counts reached to 53000 cfu/100 mL in July, with the temperature rising to the highest degree among the studied sites 32.5 °C and the nitrite concentration decreasing to the lowest value of mg. L^{-1} 0.013. In addition, a high count recorded in October 35000 cfu/100 mL associated with a relatively high turbidity of 4.16 NTU. As we noted previously, the rise in nitrogen in the tunnel water in the fall explained by the decomposition and mineralization of organic matter by nitrifying bacteria through which ammonia oxidized to nitrite and then nitrite oxidized to nitrate by microorganisms. Nitrification is associated with an increase in bacterial counts, especially opportunistic bacteria, as a side effect of nitrification (HPC and *Ps. aeruginosa*) [38]. On the other hand, the lowest count of tunnel waters recorded in May 546 cfu/100 mL, associated with the lowest temperature of 21C°. The accumulation of nitrite 0.025 mg. L^{-1} observed with this Pseudomonas count, as the coefficient of determination will show the inverse relationship between Pseudomonas and nitrites [39]. The positive coefficient shows the significance of the relationship between *Ps. aeruginosa* and HPC bacteria in the studied sites and thus could be predicted by measuring the general counts of heterotrophic bacteria (Figures. 13, 15). In addition, it turns out that the strongest prediction is in the anaerobic tunnel conditions, and this will be representative of the behavior of bacteria in the water of the networks in the future for drinking water pipes in Lattakia city. A study [40] confirms that, contrary to what is expected, drinking water can contain *Ps. aeruginosa* when it comes from springs and the association is Significant ($P<0.05$) and the probability of *Ps. aeruginosa* being present when the HPC count is greater than 100 cfu/ml .

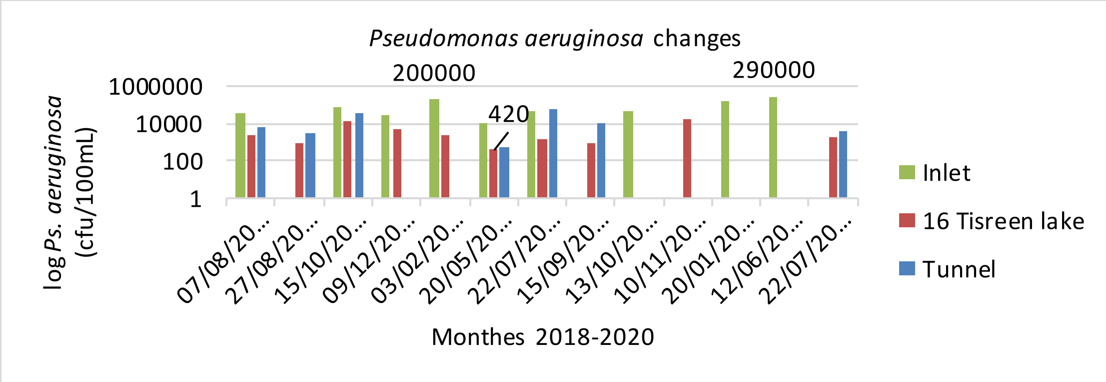


Figure 12. ***Ps. aeruginosa*** **count Changes in the Al Kabeer Al Shamali River waters.**

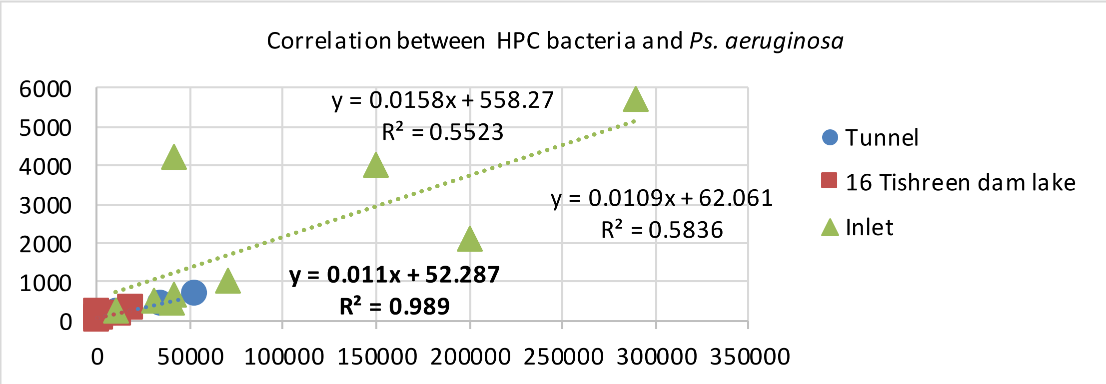


Figure 13. A Scatter Plot showed high positive correlation between HPC bacteria and *Ps. aeruginosa*.

A Scatter Plot showed high positive correlation between *Ps. aeruginosa* and NH_4^+ (Fig. 14). We discuss in Previous the same trend between faecal bacteria and HPC bacteria study elevation of ammonia in the aquatic environment due to natural excretion and high metabolic rate has been confirmed by [41]. Changes in environmental parameters have been shown to alter the structure of bacterial communities in the water of aquaculture systems, and bacteria play a role in bioremediation of polluted water. Pseudomonas has been reported to be a predominant microorganism in aquaculture systems. It has been shown to play a role in heterotrophic nitrification activity [41].

the high counts of *Ps. aeruginosa* in the river water may explained by [42], which indicates a faster growth of *Ps. aeruginosa* found in the sewage water because the use of nitrate as a final acceptor for electrons.

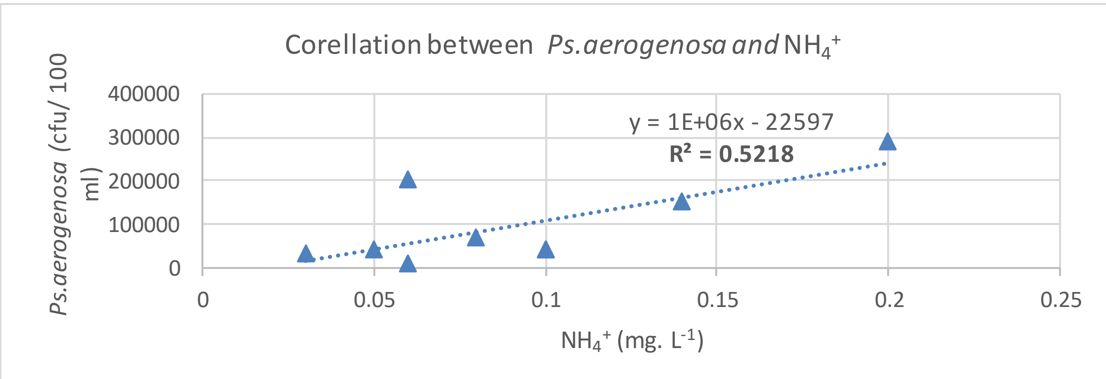
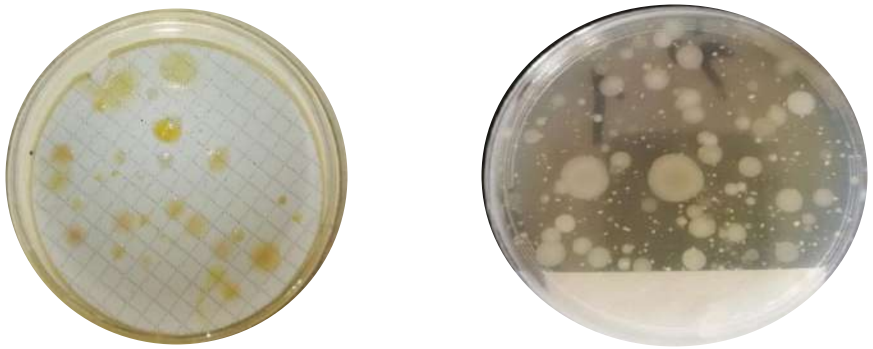
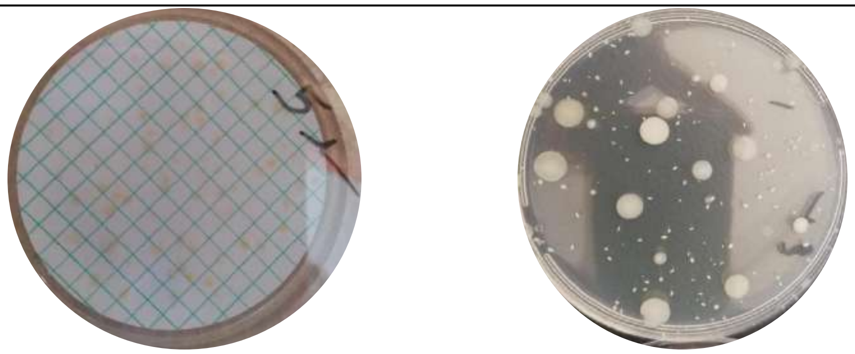


Fig. 14. A Scatter Plot showed positive correlation between *Ps. aeruginosa and* NH_4^+ **in Ghammam water.**

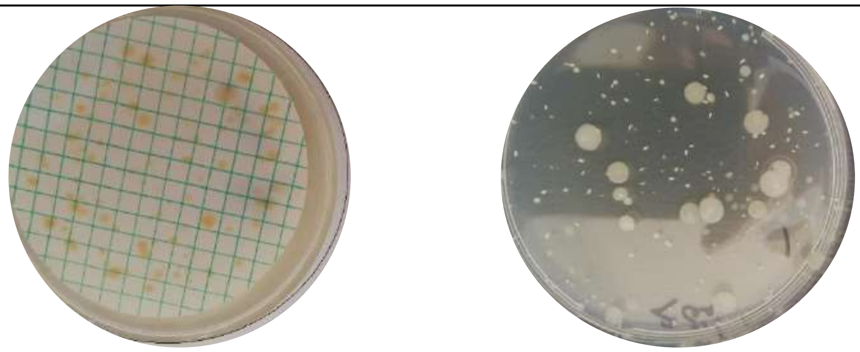
In previous study [19] when researched Non- Purgeable Organic Carbon NPOC concentrations in Al-Kabeer Al-Shamali River showed significant differences ($p<0.05$). The mean carbon concentrations ranged between (2.84 mg. L^{-1}) in water inlet, then increased to (3.24 mg. L^{-1}) in the water of 16 Tishreen dam lake, then decreased to (2.70 mg. L-1) in the outlet. Therefore, these water characteristic could enhance *Pseudomonas. Aeruginosa* to grow and multiply.



Ps. Aeruginosa colonies on Cetrimid Agar in lake inlet water	**HPC bacteria colonies in lake inlet water**



***Ps. Aeruginosa* colonies in 16 Tishreen dam lake water**	**HPC bacteria colonies in 16 Tishreen dam lake water**



***Ps. Aeruginosa* colonies in tunnel**	**HPC bacteria colonies in tunnel**

Figure 15. *Ps. Aeruginosa* colonies (left) and HPC bacteria colonies (right) in current study.

A study [43] indicates that some of *Ps. Aeruginosa* Removal of nitrates under aerobic conditions by the process of Aerobic-Heterotrophic Denitrification at low values of C: N and at low temperatures and in the presence of a source of carbon.

previous Studies [3], [8], [43] results showed significant differences ($p<0.05$) between sites for heterotrophic bacteria, Total coliform, Thermotolerant Coliforms bacteria, *Enterococcus faecalis*, Multiple Tube Fermentation Technique (Fig. 16). Inlet water recorded the highest counts in February, reaching 37000 cfu/100 mL for TC; 3200 cfu/100 mL for TTC; and 1580 cfu/100 mL for *Ent. Faecalis*. These counts when compared by *Ps. Aeruginosa* counts

We will see the dominance of *Ps. Aeruginosa* in the three locations, this is confirmed by [42], which says that *Ps. Aeruginosa* have the ability to Use a wider range of organic molecules as sources of carbon and energy compared to Enterobacteriaceae.

Table 3. Statistical analysis of the studied bacterial indicators in the waters of the selected sites.

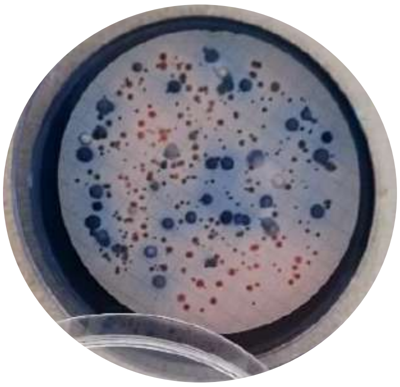
	Ps. aeruginosa	**FC**	**HPC**	
Inlet Al Kabeer Al Shamali River Ghammam bridge	97250.00	641.11	2097.78	Mean
	31751.31	365.35	676.33	St. Err
	95253.94	1096.06	2028.99	St. Dev
	10000.00	32.00	230.00	Min
	290000.00	3200.00	5700.00	Max
	9.00	9.00	9.00	Count
16 16 Tishreen Dam Lake	4766.00	31.73	114.13	Mean
	1965.01	8.41	28.10	St. Err
	6213.91	27.88	88.85	St. Dev
	420.00	0.00	10.00	Min
	19000.00	80.00	310.00	Max
	10.00	11.00	10.00	Count
	16265.14	121.13	230.50	Mean
Outlet Ain al-Bayda irri-gation tunnel	7527.92	57.51	82.94	St. Err
	19917.01	162.67	219.44	St. Dev
	506.00	0.00	50.00	Min
	53000.00	460.00	650.00	Max
	7.00	8.00	7.00	Count

Correlations between the studied bacterial indicators: It was found that there is a strong correlation between the mentioned groups (Table 4), and this is alike with the study of [44]

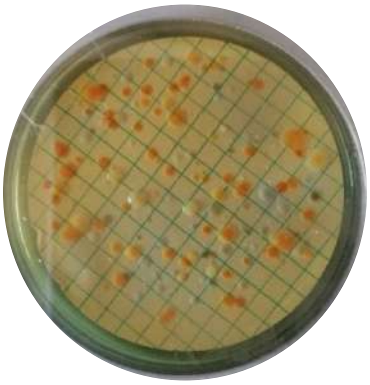
Table 4. Correlations between *Ps. aeruginosa* and TC, TTC, MPN, and Ent. faecalis, and HPC.

Sample sites	Bacteria group	TC	TTC	MPN	*Ent. faecalis*	*Ps. aeruginosa*	HPC
Inlet	TC	1					
	FC	0.96	1				
	MPN	0.8	0.78	1			
	Ent. faecalis	1	1	0.77	1		
	Ps. aeruginosa	0.48	0.54	0.3	0.96	1	
	HPC	0.1	0.21	0.08	0.93	0.74	1
16 Tishreen dam lake	TC	1					
	FC	0.72	1				
	MPN	0.54	0.94	1			
	Ent. faecalis	0.42	0.2	0.35	1		
	Ps. aeruginosa	0.08	0.27	-0.01	0.88	1	
	HPC	0.43	0.52	0.63	0.75	0.76	1
Outlet	TC	1					
	FC	0.9	1				
	MPN	0.57	0.85	1			

Ent. faecalis	0.28	0.55	0.45	1		
Ps. aeruginosa	0.51	0.77	0.71	0.95	1	
HPC	0.46	0.72	0.65	0.97	0.99	1

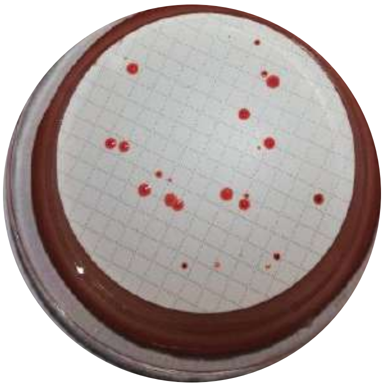


Thermotolerant Coliformsbacteria (TTC) colonies on MFC agar (blue metalic colony)



Total coliform Bactria colonies on Tergitol-7 Agar

Multiple Tube Fermentation test via Brilliant Green Bile Lactose broth



Enterococcus faecalis colonies on Enterococci Selective Agar

Figure 16. Photos for studied bacterial indicators.

The previous study [45] indicates that the higher C / N is favorable for microbial proliferation and for ammonia removal, and this observed in autumn samples. [46] The total nitrogen (TN) removal efficiency of the process increased with increasing the C/N ratio and decreasing the DO concentration. Due to substrate competition between heterotrophs and aerobic denitrifies. The most important findings of the current bacteriological study:

a) Bioremediation plays an important role in decreasing C: N in the tunnel compared to 16^{th} dam lake may be *Ps. aeruginosa* play a major role in this process.
b) Deposition of lime biologically and physically in the waters of the dam lake.

Canadian Water Quality Index (CCME WQI) Results of the studied sites: It was calculated according to the model as follows: The Scope measure is F1 representing the percentage of variables exceeding standard limits compared to the total number of variables. It represents the extent of non-compliance with water quality standards over a given period of time.

$$F1 = \left[\frac{Number\ \ of\ \ faild\ \ variables}{Total\ \ number\ \ of\ \ variables}\right] \times 100$$

Frequency scale is F2. The percentage of individual tests exceeding standard limits over the total number of tests.

$$F2 = \left[\frac{Number \ \ of \ \ faild \ \ tests}{Total \ \ number \ \ of \ \ tests}\right] \times 100$$

Amplitude F3 represents the amount of passed tests that do not meet the specifications and is calculated in three stages:

The first stage: calculating the deviation. It is the number of times that the individual concentration is greater than (or less, when the target is the lower limit) the allowable limit and is calculated as follows: When the test concentration should not exceed the permissible limit:

$$Excursion_i = \left(\frac{faild \ \ test \ \ value_i}{Objective \ \ j}\right) - 1 \qquad (3a)$$

When the test value should not be less than the permissible limit:

$$Excursion_i = \left(\frac{Objective \ \ j}{faild \ \ test \ \ value_i}\right) - 1 \qquad (3b)$$

The second stage – calculating the normalized sum of excursions, nse, which is the sum of the individual tests passed and is calculated by adding the individual deviations and dividing them by the number of the total tests. This variable is called the sum of the modified deviations and is calculated as follows:

$$nse = \frac{\sum_{i=1}^{n} excursion \ \ i}{Number \ \ of \ \ tests} \qquad (4)$$

The third stage: F3 is calculated through the following equation:

$$F3 = \quad nse/(0.01 \ \ nse + 0.01) \qquad (5)$$

After finding the three factors, the Canadian index is calculated from the following equation:

$$CCMEWQ = 100 - \left[\frac{\sqrt{F_1{}^2 + F_2{}^2 + F_3^2 I}}{1.732}\right] \qquad (6)$$

The constant 1.732 adjusts the result of the index value and makes it confined between 0-100.

These three factors combine to produce a value between 0 and 100 representing the total water quality, where 0 indicates the "worst" water quality and 100 indicates the "best" water quality. The parameters used to calculate the CCME WQI are listed in (Table 5). The results of the CCME WQI water assessment showed that the river water is moderately class III C (64) due to the high number of TTC and turbidity bacteria (Table 6). The water of 16 Tishreen Dam Lake (90) is good, second class B, and the lake outlet is also 89.88, respectively, due to sedimentation and low fecal bacterial counts (Table 6). The model was applied to the Nile River by the researcher [47], [48] and used to give the changes that occur in the Nile river water for the purpose of drinking, irrigation, wildlife and livestock at the right time.

Table 6. Water quality parameters used in the CCME WQI calculation in Al Kabeer Al Shamali River.

Date	Locations	TTC	PO_4^{-3}	NO_3^-	TDS	EC	PH	TUR
Units		CFU/100 mL		mg/L		µS/cm		Ntu
07/08/2018	Inlet	35	0.22	1.6	321	668	8.06	26.2
15/10/2018		80	0.24	1.8	330	690	8.1	19.9
09/12/2018		80	0.45	4	353	739	8.04	11.2
03/02/2019		**3200**	0.19	3.1	333	714	7.96	18
20/05/2019		**210**	0.09	1.4	311	645	7.9	**1.52**
22/07/2019		100	0.32	1.3	294	613	8.13	6.13
13/10/2019		32	0.06	2.2	284	593	8.02	10.9

20/01/2020		**1700**	0.07	2	337	715	8.1	**3.98**
12/06/2020		**333**	0.13	1.9	304	634	8.01	31
07/08/2018	16 Tishreen Dam Lake	12	0.16	1.5	273	568	7.92	**2.6**
27/08/2018		59	0.1	0.9	359	598	7.8	**1.3**
15/10/2018		46	0.06	1.8	275	576	8.03	**3.88**
09/12/2018		25	0.07	1	297	620	7.8	5.15
03/02/2019		4	0.23	2.1	289	609	7.75	**0.41**
20/05/2019		0	0.05	1.6	317	661	7.75	**2.27**
22/07/2019		52	0.45	0.6	305	636	8.11	**3.02**
15/09/2019		80	0.03	0.9	301	616	7.95	**4.64**
10/11/2019		56	0.01	0.9	302	628	7.93	13.2
22/07/2020		15	0.18	0.6	282	591	8.01	**3.23**
29/04/2018	Outlet	3	0.29	2.9	315	634	7.41	**1.2**
07/08/2018		60	0.18	1.6	288	602	7.81	**2.32**
27/08/2018		136	0.15	0.8	357	595	7.7	**1.7**
15/10/2018		**460**[1]	0.25	2.4	283	593	8	**0.37**
20/05/2019		0	0.05	1.8	329	686	7.81	**4.16**
22/07/2019		**260**	0.41	1.2	336	700	7.97	**2.63**
15/09/2019		30	0.06	0.7	300	622	8.06	**4.2**
22/07/2020		20	0.32	0.5	308	639	7.88	**2.79**
S.N.S 2007 Standards		0	1	50	1200	2000	6.5-9	**1**
WHO 2007		0		50	1000	1500	6.5- 8.5	**1**

[1] Bolded values do not meet the objective.

Table 7. Results of the water quality categories of the studied sites based on the Canadian model.

Sampling points	F1	F2	nse	F3	CCME WQI	CCME WQI Value	water quality	Rating
Lake inlet	33.33	22.22	0.88	47	**64**	79-60	Fair	**C**
16 Tishreen Dam Lake	16.66	3.03	0.025	2.5	90	80-94	Good	B
Lake outlet (tunnel)	16.66	4.16	0.035	3.5	89.88	80-94	Good	B

Table 8. Classification of the studied sites according to the Canadian Council of Environment Ministers Water Quality Index [26].

Sampling points	Rat-ing	CCME WQI	CCME WQI categories
16 Tishreen Dam Lake Lake outlet (tunnel)	**Good**	94-80	water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

Lake inlet	**Fair**	79-60	water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels

The model used to assess water quality does not correlate with other biological indicators [24], [49] and therefore a detailed bacteriological evaluation was required.

4. Conclusions

The results of the Canadian water quality assessment CCME WQI showed that the river water is moderate of the third degree C, and the 16th Tishreen Dam Lake water and the outlet of the lake is good of the second degree B due to sedimentation and low counts of fecal bacteria. The results approved the positive aspect of establishing the dam lake and the tunnel. But on the other hand the Ps. aeruginosa showed significant differences between the studied sites also and that's could be challenge when using Dam Lake and irrigation tunnel water as a source for drinking water.

- The river water recorded the highest count for Ps. aeruginosa. in Jun reaching 290000 cfu/100 mL and spatial analysis showed that Ps. aeruginosa counts for the river samples correlate with NH_4^+ (r =0.72) these refer to recent pollution and direct disposal sewage to the river.
- Ps. aeruginosa decreased in 16th Tishreen Dam Lake water to the lowest count 420 cfu/100 ml in May and to 1000 cfu/100 mL in August, these decrease may due to stratification and to environmental stresses.
- Ps. Aeruginosa counts were higher in the outlet Ain al-Bayda irrigation tunnel than 16th Tishreen Dam Lake and reached 53000 cfu/ 100 ml in July, Due to release of bacteria from soil and sediment and not necessarily recent contamination.
- A positive correlation was recorded between Ps. aeruginosa and HPC in the studied sites and thus can be predicted by measuring the HPC bacteria. It turns out that the strongest prediction is in anaerobic tunnel conditions (r =0.98), and this will be representative of the behavior of microbes in the water pipes in the future.
- A positive correlation between Ps. aeruginosa and NH_4^+. That's mean Bacteria play a role in treating polluted water.
- Pseudomonas has been reported to be a predominant microorganism in the current research.
- The water temperatures and nutrients support the growth of these organisms.
- We recommend that Ps. Aeruginosa must be mentioned in the Syrian drinking water standards.

The water coming out of the tunnel agree with the drinking water standards and other domestic uses from the physicochemical point, but of microbiological view *Ps. aeruginosa* counts exceeded the permissible limits as drinking water in all sites. These microbial concentrations provide the basis for choosing appropriate sterilization methods to reach health goals within the drinking water safety plan. The filtration procedure (so that the turbidity does not exceed 1NTU). And disinfection used in drinking water, which so a water treatment plant must convert the tunnel water into drinking water, so that it can be connected to the drinking water network in Lattakia city.

Finally, after determining the type of water, appropriate methods of water treatment must be taken.

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No Supplementary Materials.

Author Contributions:

A. Mahmoud; methodology, writing—original draft preparation, A. Mahmoud and M. Y. Khudair writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement:

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Data Availability Statement:

No Data Availability Statement.

Conflicts of Interest:

The authors declare no conflict of interest.

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