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Statistical analysis for water quality data using ANOVA (Case study – Lake Burullus influent drains)

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ABSTRACT

Lake Burullus is considered one of the most valuable northern lakes in Egypt due to its unique ecological system and special location. Over the past four decades, the lake has suffered from high contamination levels due to expansion in fish farming and increasing of agricultural drainage water entering the southern side of the lake through eight influent drains. This research aims to assess the current situation of the lake's influent drains. For this purpose, two types of statistical analysis, Mean average method, and Analysis of Variance (ANOVA) were used. The water quality conditions for six major drains (Therah (Tira), Nashart, Zaghloul drain, Drain 7, Drain 8, and Drain 11) have been evaluated with respect to the limits of the Egyptian regulations (law No. 48/1982). First drain chemical pollution index (DCPI) was used to classify the influent drains categories (from excellent to bad) with respect to the water quality conditions. After that the hotspots for domestic, industrial wastewater and agricultural drainage water have been specified using ANOVA. The analysis was conducted using the data compiled during 2018, 2019, and 2020 for six main parameters (BOD, DO, NH_4, NO_3, TSS, and TDS). The results show that Nashart, Tira and Zaghloul drains should have priority to be treated due to their relatively bad water quality conditions and Nashart drain is considered the worst of them. Also, the comparison between the Mean average statistical analysis method and one-way ANOVA shows that ANOVA is more reliable because it considers many parameters at the same time plus considering the frequency trend. the adopted approach and techniques in this study can help the decision makers in setting the priorities for the rehabilitation projects of the agricultural drains in Egypt.

1. Introduction

The Egyptian northern lakes used to be one of the main sources for fishing. In the past, they supplied more than half of Egypt's fish catch. In 2016, however, they contributed to just approximately 10 % of the catch. Mariout, Edku, Manzala, Burullus, and Bardawil are five lakes on Egypt's northern coast which account for approximately 77 % of all fish collected in Egyptian lakes [10]. Egypt's north coast's most valuable environmental lake is Lake Burullus. Unfortunately, this lake suffers from high contamination levels. The high level of contamination in Lake Burullus is placing extensive stress on the lake's ecosystem causing serious repercussions on the aquatic life in the lake and the human health of the surrounding communities [2]. Pollutants sources includes untreated home sewage, waste from fish farms, industrial waste, and agricultural drains that served 350,000 feddanOne fresh-to-salt water canal and eight drains effluent (3900 million m3/year), which sources are fish farms, farmland, and cities, discharge into the lake annually. The Lake's Mediterranean water is salty. Effluents drains is discharged into Lake Burullus, which contains heavy loads of fertilizers, insecticides and oxidized organic remains that have caused severe water quality and eutrophication problems [15,20].

The state of a lake and its ecosystem is directly related to the quality of its water. Lake water quality may be affected by several external causes, including pollution, runoff from land, and climate change. Low levels of oxygen and algal blooms are only two of the many problems that might result from water that isn't of high enough quality. Lake Burullus is the second largest coastal lagoon in Egypt, although its ecosystem has suffered due to its central placement inside the Nile-Delta, from which it gets most of the region's drainage water via several agricultural drains. Agricultural fertilizer and toxic metals pollute the freshwater that drains off the land [11,16]. The Egyptian Environmental Affairs Agency EEAA prioritized water quality maintenance in these

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lakes, with a focus on the critically important Lake Burullus, because of the water quality decline along the Egyptian coast. The first stage in water quality management is conducting a water quality assessment to determine the state of the drainage region. Heavy metals and nutrients are becoming increasingly concentrated in lakes due to a few factors, including the introduction of untreated sewage, the growth of aquaculture near lake shores, and the extension of irrigated farmland. Adding a second artificial outlet for the lake or constructing drain discharge treatment facilities were the two most cost-effective options for bettering the lake's water quality [8].

High levels of organic matter in Lake Burullus have led to the lake's classification as having poor, deteriorating water quality according to the trophic status index [7]. Drainage water pollution, as determined by [12], causes higher amounts of Zn, Fe, Cu, Cd, and Pb in the water of Lake Burullus on its southern shores compared to its northern shores. Mean heavy metal levels decreased as follows, according to research conducted by El-Alfy et al. [5]: the arrangement according to the study from the highest to the lowest respectively Mn,Fe, Zn, Co, Cu, Cd, Ni, Pb and Cr. All the samples had Cd levels that were higher than what is considered acceptable for sediment. According to Hany et al. [11], the examined water quality indicators improved significantly in the lake inlet and the eastern section, where the dredging operation was carried out, but improved less in the western part. The influent drains that discharge into the lake are considered one of the major reasons of water deterioration in the lake. Therefore, it becomes crucial to find solutions to improve the water quality of the influent drains which will consequently improve the water quality in the lake.

The first step to treat the water body is to assess the present condition. So, the aim of this research is to assess the influent drains of Lake Burullus. There are many methods used in assessing the water bodies quality. One of these methods is (Analysis of Variance) ANOVA which is a statistical method used for getting more accurate data depending on (maximum, minimum, mean average). Much research has been conducted and utilized the two-way ANOVA to evaluate the quality of water. In 2017, Vishnu Radhan et al. [18] used ANOVA to assess the water quality near Malaysia's cities. Water quality parameters (pH, TDS, DO, and BOD) were studied, and the results show that the water quality is declining dramatically for the studied area. Additionally, it claimed that the side rivers on the Malaysian peninsula were more contaminated than the main river. Consequently, maintaining the settings will be able to address issues and prevent the oxygen from running low. Tiri et al. [17] studied the water quality of Koudiat Medouar, in East Algeria, using a mixture of hierarchical cluster analysis (HCA) and analysis of variance (ANOVA). According to this study, the water in this region is alkaline, which indicates that it has a high electrical conductivity, and it is found that variables Mg, Ca, HCO_3, pH, NO3 and SO_4 were all considered crucial for study observing station.

Mohsen M. Yousry and El Gammal [19] compared the mean values of Nile River surface water quality parameters by using ANOVA with standards of Law 48/year 1982 when compared to their mean levels. COD had slightly higher levels. These factors explain over 74.7 % and 67.1 % due to agricultural uses mixed (TDS, TSS, and nitrate) during February and agricultural uses mixed with residential wastewater (TDS, BOD, and nitrate) during August cause water quality fluctuations. Bacterial pollution ranks second and third in August and February, respectively. TDS, TSS, NO3, BOD, COD, FC, TC, pH, and DO were the most essential indicator parameters for water quality index calculation according to Varimax rotated factors for the first three rotated variates along the Nile during August the arrangement according to the study from the highest to the lowest respectively (FC, pH, NO3, TC, TDS, BOD, TSS, DO and COD). Factor analysis can assist decision makers measure pollution using practical indicators.

[6] explained that studying of heavy metals in the aquatic system can give important information about the amount of pollution in the environment. Lee and Wendy [13] suggested by using ANOVA that heavy metals might be in Lake Burullus because fertilizer waste from farms got into the water system. Fe, Mn, Cu, Zn, and Cd each had between 308 and 765, 43.4 to 97.8, 16.2 to 38.6, 28.0 to 92.8, and 0.40 to 4.60 g/L. The amount of metal in different places and at different times of the year was very different (P less than 0.05). This trend of ANOVA could be caused by the effect of sewage effluents from several drains, where organic matter levels are rising, and layers are clay-like [12]. But Cu and Cd amounts in many samples were higher than the British Columbia Ministry of Environment and Climate Change Strategy's chronic standards for freshwater (10.6 and 0.46 g/L) and saltwater (2 and 0.12 g/L). On the other hand, El-Alfy et al. [5] found by using ANOVA that Cd is a flaw in many chemicals, such as phosphate fertilizers. The Cu and Cd in the drainage water are often blamed for this, and agricultural goods are one of the main sources of these metals [4]. Positive correlations of ANOVA ($n = 12$, P less than 0.05) between Cu/Cd levels in the winter ($r = 0.83$) and summer ($r = 0.77$) showed that they both came from farming chemicals. As a result, Cu and Cd got into the lake water, which hurt the ecosystem and other living things [14].

Al-Afify et al. [3] used ANOVA to assess the water quality condition of Lake Burullus. The research showed that according to Water Quality Index (WQI), Lake Burullus was including various bacterial groups in its influent drains water and heavy metals in most lake stations. Moreover, DO, NH_3-N, Cu, and Cd have the biggest effect on (WQI), which indicates the presence of excessive discharge from agricultural drains. Twenty-nine percent of lake water samples had low metallic pollution, 33 % of samples had moderate heavy metal pollution, and lastly, 38 % had high metallic pollution.

From the previous literature, it was found that lake Burullus influent drains are highly contaminated, which consequently affects the water quality in the lake itself. Therefore, it becomes a must to monitor these drains and assess them to highlight the hotspot areas which have the priorities for treatment in order to improve the quality of water and the aquatic life in both the drains and the lake. Conducting a comprehensive statistical analysis of the water quality data from those drains is considered an important step towards the better understanding of the current situation and providing a tool for the prioritization of the water quality improvement plans.

2. Research objective

Lake Burullus water quality is affected by domestic waste, fish farms wastes, agriculture farms and it is highly affected by its influent drains which dump their waste into the lake. The goal of this study is to assess the lake's influent drains and find the Drain Chemical Pollution Index (DCPI) to evaluate the drains water quality condition with respect to the law 48 limits and to realize the hotspots for domestic wastewater, agricultural waste, industrial waste, or a mixture of these. The study focuses on Therah (Tira), Nashart, Zaughloul drain, Drain7, Drain8, and Drain11. The data analysis was conducted during 2018, 2019, and 2020 during. The study is considered as an evaluation of lake Burullus drains area using ANOVA for WQD. Drains assessment will help the decision maker of the rehabilitation project of Egypt villages to evaluate the current situation and to select the drains that have the most priority to be treated which will improve the water condition of drains and lake.

3. Material and methods

3.1. Research area

Lake Burullus is one of the largest coastal lakes in Egypt. It is located between the Delta branches. Lake's coordinates are 31° 36′ N and 30° 33′ E in north - west, 31° 36′ N and 31° 07′ E in the north – east, 31° 22′ N and 30° 33′ E in the south – east, 31° 22′ N and 31° 07′ E in the south – east. The area of the lake is 420 km^2 and 54-km-long on the Mediterranean side of the lake. From west to east, the land is between 3 km and 12 km wide. Except for the entrance, where the water can get as deep as 4 m, most of the lake is only 0.4 to 2.0 m deep [1]. The main sources of water are the Burullus West Drain, drain 11, Nashart drain (Drain9), drain 8, drain 7, Tira Drain, Zaghloul drain, Burullus drain, and the Bermbal canal. Fig. 1 shows the map of Lake Burullus drains and the location of monitoring stations. The major source of wastewater comes from the agricultural area, which, according to the research study, the drains about 350,000 feddan. This part of the Nile Delta has a high average population density that is approximately 1540 cap per square kilometer, so the drainage area has a high intensity. Agricultural runoff water (3.9 billion m^3/year) is discharged into Lake Burullus through seven drains; this water carries with it significant loads of pesticides, oxidized organic debris, and fertilizers from nearby farms and industries [15,20].

3.2. Data collection

Studied drains were monitored monthly from August 2018 to July 2020 by the Housing and Building National Research Center (HBRC). Six parameters of water quality were recorded (Dissolved-Oxygen (DO), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), Ammonium (NH_4), Nitrate (NO3), and Total Suspended Solids (TSS). as well as the flow rate of all drains. The eastern, middle, and western basins of lake Burullus are split. Fig. 1 shows the sampling details, including their latitude and longitude, and includes the name of the drain and sample location for each drain. For example, Nashart drain is located at 31°31′22.15″ Latitude and 31° 5′51.36″ Longitude. At the outfall, 241 samples were taken for all stations.

3.3. Research methodology

Fig. 2 illustrates the flow chart of the study methodology. The study outline starts with sample data which was collected for Lake Burullus influent drains. Then, water quality data was classified according to characterization (Physical, Chemical, Anions and cations). The study utilized two types of statistical analysis, Mean average method, and ANOVA.

Based on the average mean and risk assessment, a drain chemical pollution index (DCPI) was calculated, taking into consideration agricultural waste, domestic waste, and industrial waste. The results used to classify the influent drains categories (from excellent to bad). Then, an evaluation of the drains was conducted using the two statistical methods and the drains were ranked according to their water quality condition. Finally, a comparison between the results of the used methods have been carried out.

Fig. 1. ArcGIS Map of Lake Burullus drains with selected drains stations.

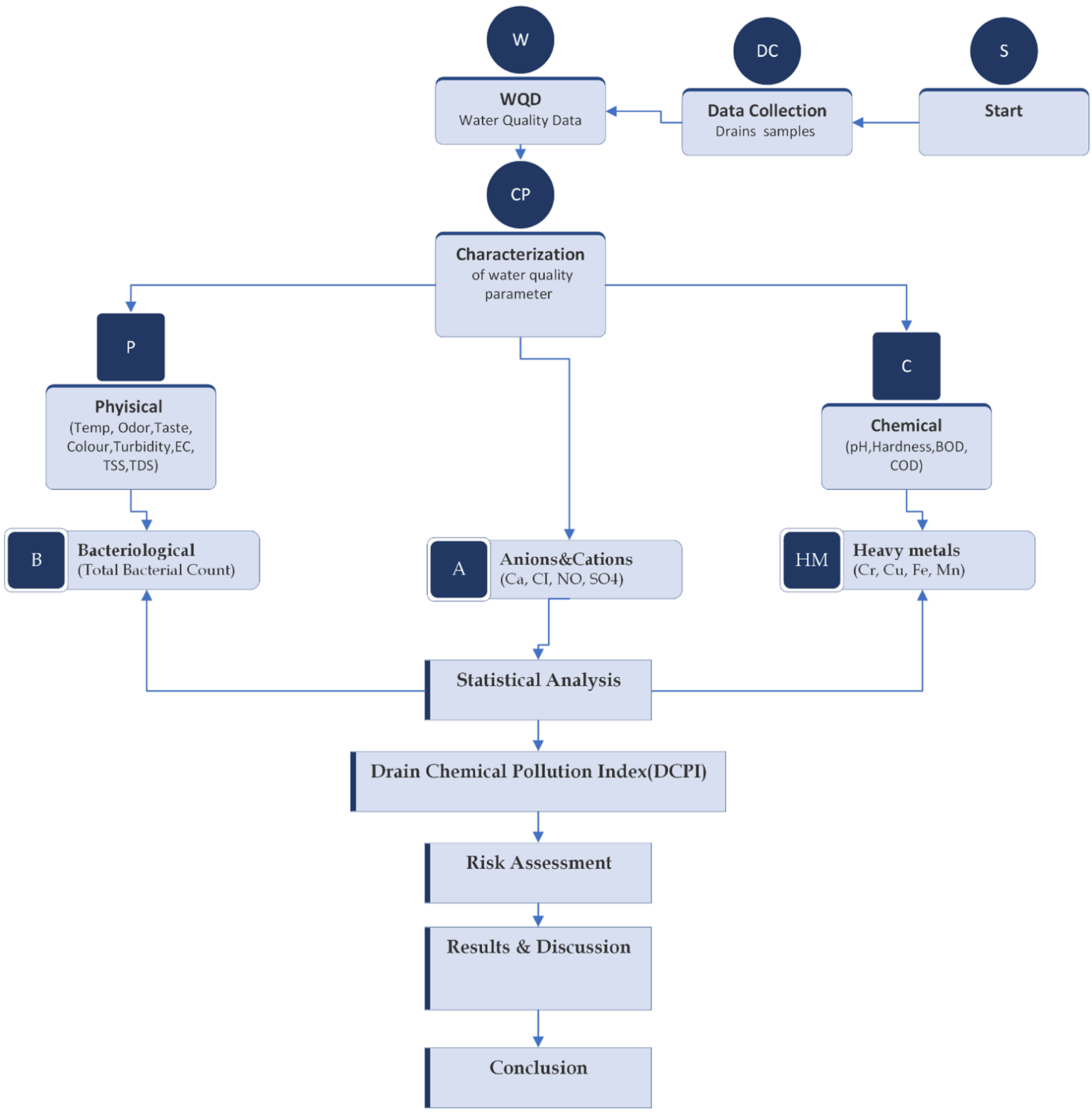

Fig. 2. Flow chart of the study Methodology.

4. Results and analysis

Water quality data was utilized to identify the drains with high pollution levels. First, the DCPI assigned a unique index of each station depending on the concentration of pollutants in each drain according to the defined chemical parameters. Then, the studied drains were prioritized for treatment based on the analysis results by ANOVA considering the maximum frequency repeated data.

4.1. Classification of studied drains according to DCPI

As shown in Table 1, the chemical pollution index divides the water quality parameters into two groups. The first group includes DO, NH_3 and BOD. The index varies from one to ten. Ten means very poor water quality while one means excellent water quality conditions. The second group includes NO_3 -, $PO_{4\text{-}3}$, TSS, and TDS. The index varies from one to five. The highest index value 5 indicates extremely bad conditions and the lowest index value 1 indicates excellent conditions.

The score classes were chosen based on the literature's descriptions of concentrations in extremely polluted and uncontaminated areas. [9]. The WQD average mean for each parameter of each drains samples through the study period was compared with chemical pollution index which is shown in Table 1(index ranking). It is found that Lake Burullus influent drains are considered as a "Bad category" in the two groups as all the parameters mean value are over the category as shown in Tables 2 (calculated index for the case study).

4.2. ANOVA analysis technique

A one-way ANOVA is used to analyze the WQD (BOD, DO, NH4, TSS, TDS and NO_3) through the study period. A statistical examination was conducted to qualify the water quality parameters data. The water quality data which recorded p-value less than α value of 0.05, where α indicates a five percent deviation of the mean values, are considered reliable (significant) to be used in the statistical analysis as shown in Table 3. The results were selected depending on the data frequency. By

Table 1
Groups for the Chemical Pollution Index.

(A) Ammonia (NH3), Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD)

Description	Index	NH3(mg/l)	DO (mg/l)	BOD (mg/l)
Excellent	1	0 < 0.25	7+	0 < 1
Very Good	2	0.25 < 0.5	6 < 7	1 < 2
Good	3	0.5 < 1	5 < 6	2 < 4
Fair	5	1 < 2.5	3 < 5	4 < 6
Poor	7	2.5 < 5	1 < 3	6 < 10
Very Poor	9	5 < 10	0 < 1	10 < 15
Bad	10	10+	0	15+

B) Total Orthophosphate (Orth-PO4 3-), Nitrate (NO3 -), Total Suspended Solids (TSS) and Total Dissolved Solids (TDS).

Description	Index	O-PO4—(mg/l)	NO3–(mg/l)	TSS (mg/l)	TDS (mg/l)
Excellent	1	< 0.10	< 0.1	< 30	< 200
Good	2	0.1 < 0.5	0.1 < 0.5	30 < 50	200 < 300
Fair	3	0.5 < 1.0	0.5 < 1.0	50 < 100	300 < 500
Poor	4	1.0 < 2.0	1.0 < 1.5	100 < 300	500 < 800
Bad	5	2.0+	1.5+	300+	800+

Table 2
Calculated Drains' chemical pollution index (DCPI.).

(Table 2-**a)** calculated DCPI for BOD, DO, NH_3

Name	Category	Index	NH3(mg/l)	DO (mg/l)	BOD (mg/l)
Drain No-11	**Bad**	10.00	11.25	0.85	34.00
Drain No-7	**Bad**	10.00	22.45	4.01	35.00
Drain No-8	**Bad**	10.00	10.65	2.74	26.00
Zagloul drain	**Bad**	10.00	7.15	3.04	30.50
Nashart drain	**Bad**	10.00	11.37	0.31	51.00
Tira drain	**Bad**	10.00	3.40	1.98	34.50

(Table 2-**b)** Calculated DCPI for TDS, TSS, NO3, PO4-3

Name	Category	Index	O-PO4—(mg/l)	NO3–(mg/l)	TSS (mg/l)	TDS (mg/l)
Drain No-11	**Bad**	5.00	1.47	1.55	26.00	966.00
Drain No-7	**Bad**	5.00	1.33	13.55	95.00	2796.15
Drain No-8	**Bad**	5.00	0.98	9.65	27.00	1792.50
Zagloul drain	**Bad**	5.00	1.41	5.50	33.00	1589.50
Nashart drain	**Bad**	5.00	1.53	6.35	88.50	1680.32
Tira drain	**Bad**	5.00	1.14	18.45	53.00	2499.00

using this technique, it was found that Nashart drain and Tira drain are the worst drains with respect to other drains.

4.3. Comparison between the mean average statistical analysis and ANOVA analysis

The results of ANOVA analysis were compared to the results of the Mean average analysis results. Both depend on the max, min, and mean average but only ANOVA 's results take into consideration the frequency of repeating high contamination conditions with time. ANOVA shows the trend of data by showing the frequency of most repeated data along the study period the measured variance. Fig. 3 shows the technique of ANOVA with (BOD) parameter as an arrangement of the frequency of repeated data.

Table 4 presents the statistical analysis output using the Mean average technique regarding to the allowable limits. This method does not consider the variation in parameters (such as frequency) or repeated measurements. It was noticed that all drains exceed the allowable limits for all drains. Nashart drain is the worst in BOD, while Drain 11 is the worst in DO, for TDS, TSS, and NH_4, drain 7 is the worst. Tira is the worst in NO_3. Finally, the worst drains were Nashart drain, drain 11, drain 7, and Tira drain.

On the other hand, ANOVA method is considered as more reliable method due to the wide range of analysis by taking into consideration several parameters such as year, chemical parameter, change of frequency and show the trend of results as a graphical and numerical equation with the most repeated value. The worst drains from ANOVA analysis were Nashart drain, Tira drain and drain 7 due to domestic and agricultural wastes with the most repeated WQ value (shown in Table 5). The worst drain in BOD is Nashart, the worst in DO, TDS, NH_4, and NO3 is Tira drain, and the worst in TSS is drain 7. So, Tira drain, Nashart drain and drain 7 have the priority to be treated.

It was found that ANOVA technique can be used in drains assessment for any study area with a reliable result and giving suitable rearrangement of zones. Also, this adopted approach and technique can help the decision makers in setting the priorities for national rehabilitation projects for the agricultural drains in Egypt.

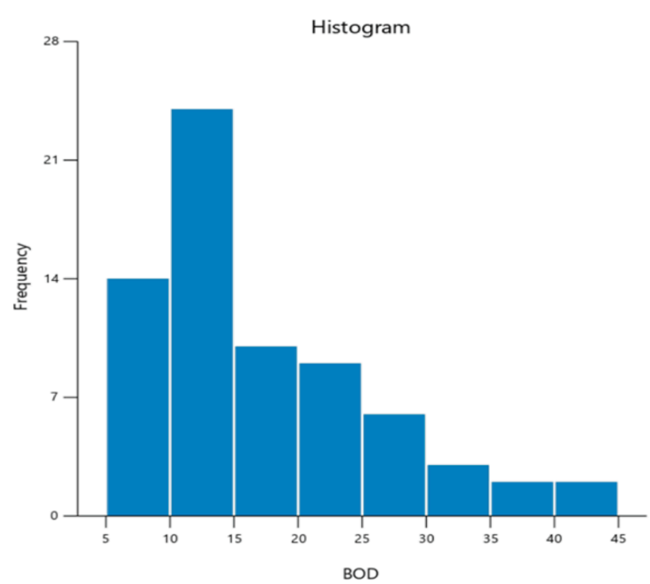

Fig. 3. Histogram plots for (BOD mg/l) and frequency circle time.

Table 3
Regression between Drain Chemical Pollution Index (DCPI) of study drains parameters.

DCPI	P-value	F-value	Std.Dev	Mean	C.V.%	R^2	Adjusted R^2	Predicted R^2	Adeq Precision
BOD	**0.0003**	**4.06**	**7.43**	**16.66**	**44.61**	**0.4074**	**0.3096**	**0.1653**	**8.2555**
DO	**< 0.0001**	**3.5**	**1.22**	**3.46**	**35.32**	**0.7292**	**0.5209**	**0.1172**	**8.9993**
NH4	**< 0.0002**	**10.35**	**4.88**	**9.03**	**49.03**	**0.5732**	**0.5266**	**0.4583**	**10.9304**
NO3	**< 0.0003**	**12.05**	**5.31**	**9.97**	**53.25**	**0.5286**	**0.5286**	**0.4592**	**11.0304**
TDS	**< 0.0004**	**6.94**	**662.47**	**2028.04**	**32.67**	**0.4392**	**0.3759**	**0.2831**	**9.6879**
TSS	**< 0.0005**	**4.08**	**26.26**	**30.51**	**86.06**	**0.2381**	**0.2381**	**0.1175**	**6.6587**

Table 4
The water quality data (WQD) for study drains with MAX & MIN values at study period.

NAME.	Q(MCM)		BOD mg/l			COD mg/l			TSS mg/l			NO3 mg/l			NH4 mg/l			pH			TDS mg/l			Salinity			DO mg/l		
	min	max	min	AL	max	min	AL	max	min	AL	max	min	AL	max	min	AL	max	min	AL	max	min	AL	max	min	AL	max	min	AL	max
Drain No-11	26	61	9	6	50	23	10	23	11	6	41	1	30	2.1	1.5	0.5	21	7.21	7–8.5	7.91	697	650	1235	0.5	3	0.9	0.85	5	4.25
Drain No-7	28	42.6	15	6	40	34	10	34	24	6	166	6.1	30	310	1.9	0.5	600	7.26	7–8.6	9.4	1518	650	4074	1.3	3	3.8	4.01	5	9.4
Drain No-8	16.66	31.43	13	6	26	41	10	41	6	6	48	2.9	30	16.4	2.3	0.5	100	7.42	7–8.7	9.3	1367	650	2218	1.1	3	3	2.74	5	3.75
Zagloul drain	0.77	0.92	8	6	45	32	10	32	12	6	54	2.6	30	8.4	1.3	0.5	13	7.31	7–8.8	8.3	1279	650	1900	1	3	1.8	3.04	5	6.01
Nashart drain	7.23	33.00	6	6	90	43	10	113	5	6	172	0.7	30	300.9	0.74	0.5	600	7.21	7–8.9	9.5	787	650	2574	0.4	3	3.4	0.31	5	6.6
Tira drain	38.059	89.66	17	6	35	31	10	31	18	6	88	7.1	30	29.8	1.4	0.5	5.4	7.32	7–8.10	8	1581	650	3417	1.4	3	31	1.98	5	5.35

Table 5
The Build Information of water quality data (WQD)of ANOVA analysis (Max, Min, Mean and standard deviation).

Parameter	Minimum	Maximum	Mean	Std.Dev	Ratio
BOD	4	50	16.94	9.76	12.5
DO	0.85	9.39	3.41	1.77	11.05
TSS	6	172	32.43	34.03	28.67
TDS	698	4105	2035	853	5.88
NO3	0.94	29.8	10.13	7.94	31.7
NH4	0.02	8	1.8	1.44	400

5. Discussion

ANOVA was used to find the best settings for processing based on what the statistical analysis model by ANOVA should have. The analysis was done using the multicable factor, which gave the best results according to the limits of Egyptian law 48 and WHO standards methods. In the study period, DO, TSS, and NH_4 were the factors that affected the quality of the water. Fig. 4 shows that the BOD values change through the year with respect to the flow rate, and there are less minerals in the water if the conductivity goes over 6 ppm, that is not good for drains according to law 48 of the WQ limit for lakes and drains. Also, the DO concentration is found to be higher, which is good for WQ that also shows how different factors change from station to station for the year 2020. This number is also a measure of all the solids that have dissolved in drains during the study period. In the studied drains, the concentration of substance in the water has changed over time for three main reasons: the first reason is a rise in the rate of discharge from agriculture waste, the second one is the municipal waste, and the third is the change in industrial waste. During the period from (January to April) for all drains, the level of organic matter was high, but the levels of dissolved oxygen, NH_4, and NO3 were low. Finally, there was a drop in discharge and a high quantity of dissolved solids.

5.1. Studied water quality parameters

Studied water quality parameters through the worst study period year 2020 has been assessed with respect to time. The study focused on Nashart Drain as it's considered as one of the worst drains and what applies to it can be applied for any other drain. The results show that the pollution fluctuated all over the year.

5.1.1. Biological oxygen demand (BOD)

It is the measure of dissolved oxygen that aerobic organisms need for organic matter to break down in each water sample through the study period. For Nashart drain, It was found that BOD levels in the drain vary between 90 mg/l, and5 mg/l which is higher than the allowable limits. Fig. 4 shows the variation in BOD concentration through the year 2020.

5.1.2. Dissolved oxygen (DO)

It represents the total amount of oxygen available to aquatic organisms. The pollution through the different year time causes fluctuation in DO which is a significant parameter of water quality data. Fig. 5 shows the change in DO concentration through the year 2020 for Nashart drain. Nashart drain had a lowest value of DO 1.12 mg/l.

5.1.3. Nitrate (NO_3)

It is a naturally occurring type of dissolved nitrogen in soil and water. It is the plant's major source of nutrients and may be utilized as fertilizer. After consuming, nitrates (NO3) transform into nitrites (NO_2). Fig. 6 represents the change in the nitrate through the year 2020. Nashart drain recorded the maximum value of NO3 which is 11.6 mg/l.

5.1.4. Total suspended solids (TSS)

They are water particles removed with a filter. For TSS testing, a filter that has already been weighed is used to filter a sample of water.

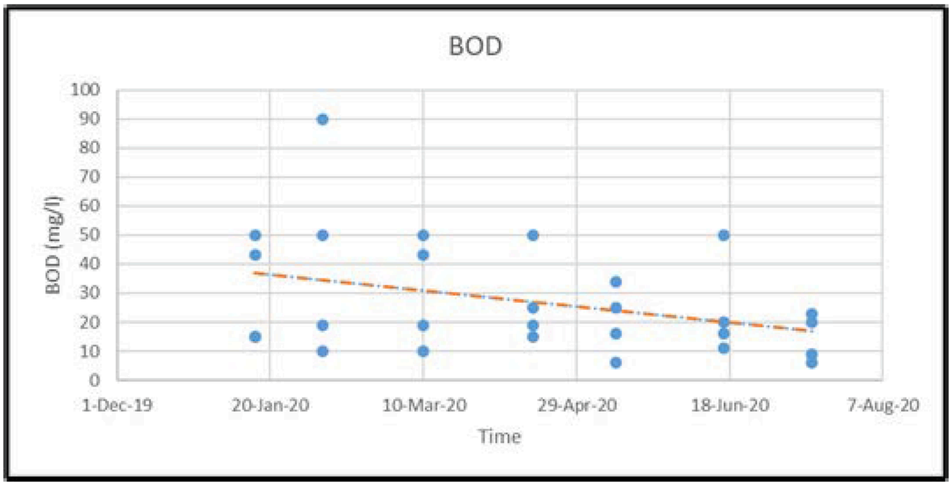

Fig. 4. Annual variations of BOD concentrations over the year 2020 for Nashart drain.

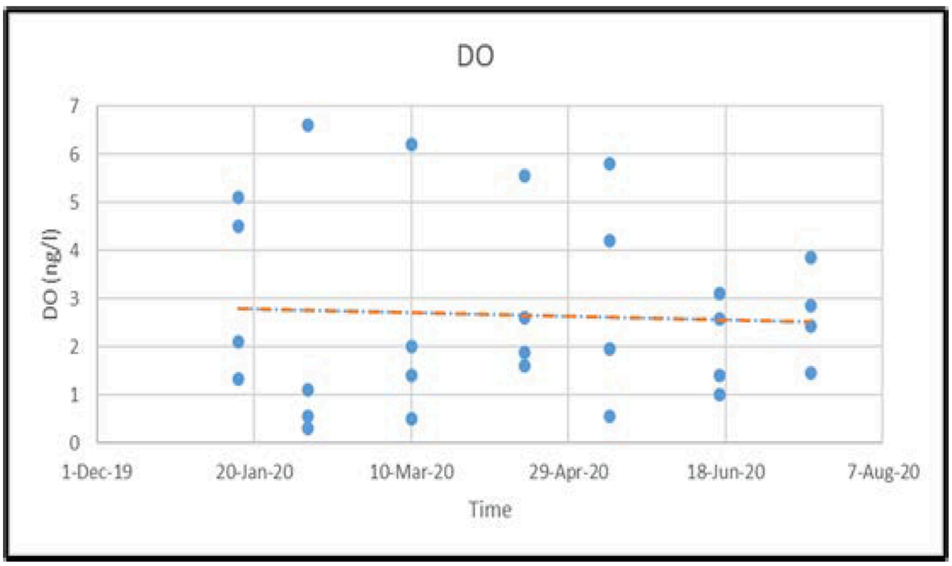

Fig. 5. Annual variations of DO over year 2020 for Nashart drain.

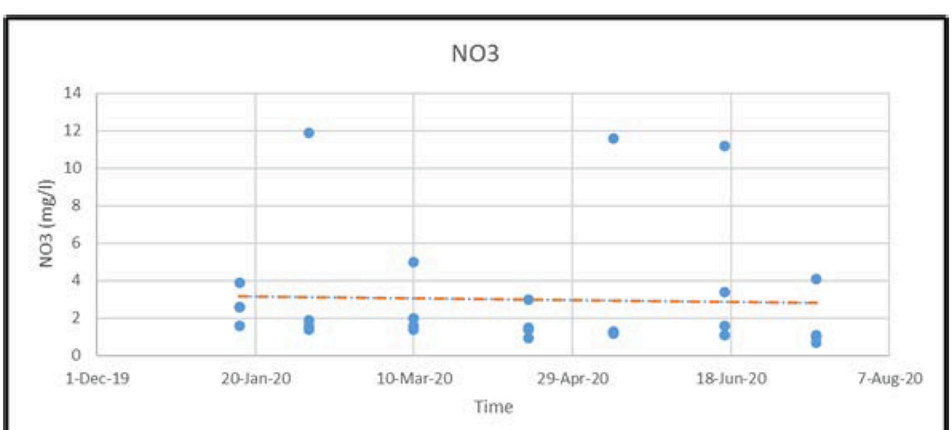

Fig. 6. Annual variations of NO3 for year 2020 *for Nashart drain.*

Fig. 7 represents the change in TSS through the year 2020. Nashart Drain has recorded the maximum value of TSS 172 mg/l.

5.1.5. Ammonium (NH_4)

There are four primary causes of excessive ammonium levels in wastewater; emissions, manufacturing exhaust, wastes from hospitals

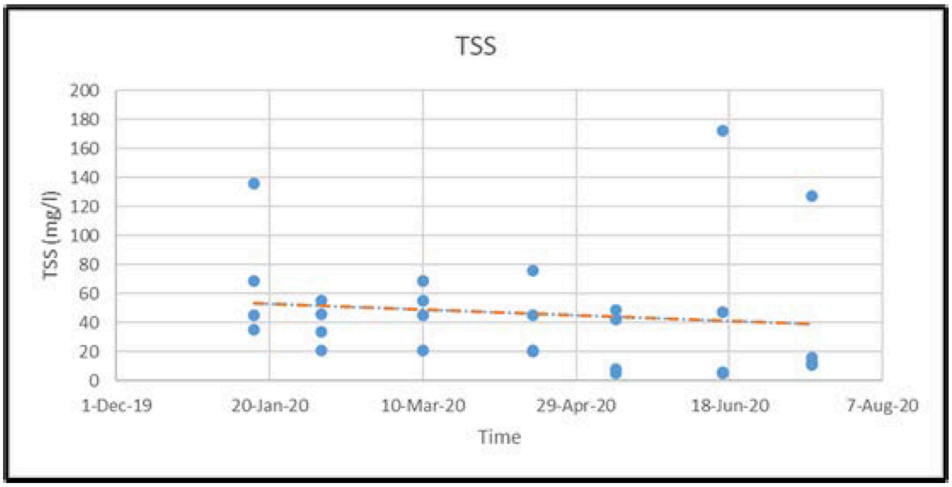

Fig. 7. Annual variations of TSS for year 2020 for Nashart drain.

and animal slaughterhouses. The release of untreated wastes that have not reached a safe level, resulting in very contaminated surface water, is also a major parameter. Fig. 8 shows the change in Ammonia concentration through the year 2020. Nashart drain has recorded a maximum value of 16 mg/l for NH_4.

5.1.6. Total dissolved solids (TDS)

Are expressed as milli-grams per liter (mg/L) and parts per million (ppm). They consist of dissolved inorganic salts, mostly calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates, and minor quantities of dissolved organic materials. According to the EPA's guidelines for secondary drainage water, drinking water should have no more than 650 ppm of TDS. Fig. 9 shows the change in the total dissolved solids through the year 2020. Nashart drain has recorded the maximum value 2574 mg/l for TDS.

5.2. Drains assessment

Chemical parameter analysis by ANOVA was utilized to rearrange and rank the drains according to the drain chemical pollution results from the worst drain to the better one. Fig. 10 shows the Boxplots for studied water quality parameters with different drains. The results show the variability of water quality parameter values which support rearrangement of the drain treatment priority. Nashart drain and Zaghloul drain have the highest BOD concentrations due to domestic load untreated, while Drain 7 and Tira drain has the highest concentrations of TDS, TSS and NO3 which may be from drainage water, agricultural waste, agricultural pesticides, and industrial waste. Tira drain and Nashart drain have the highest NH_4 concentration and lowest DO concentration which may be an indication of the presence of the drainage water, agricultural pesticides, agricultural waste.

Water quality parameter concentrations have various trends as it was observed that the high organic concentrations were recorded and low dissolved oxygen concentrations due to agricultural wastes, also decrease at NH_4 and NO_3 values. and high dissolved solids concentration. Also, the discharge was decreased through this period, and this is the main cause for water quality deterioration from (January to April) through this period. The DO concentration decreased by 33.37 % compared with the DO concentration through the study period and the concentration of BOD value changes with the variation of the water level in the drains.

Finally, the analysis showed that Nashart, Tira and Zaghloul drains have the priority to be treated due to their relatively bad water quality conditions, and Nashart drain is considered the worst of them.

6. Conclusions

Water quality data was analyzed to assess the chemical pollution index of Lake Burullus influent drains using one-way analysis of variance (ANOVA). This technique used the water quality data of 241 samples taken from nine different sites, to assess the water quality conditions considering different water quality parameters (BOD, DO, NH_4, NO3, TSS, and TDS). The Drain Chemical Pollution Index (DCPI) was calculated and showed that the drain water contains mixed

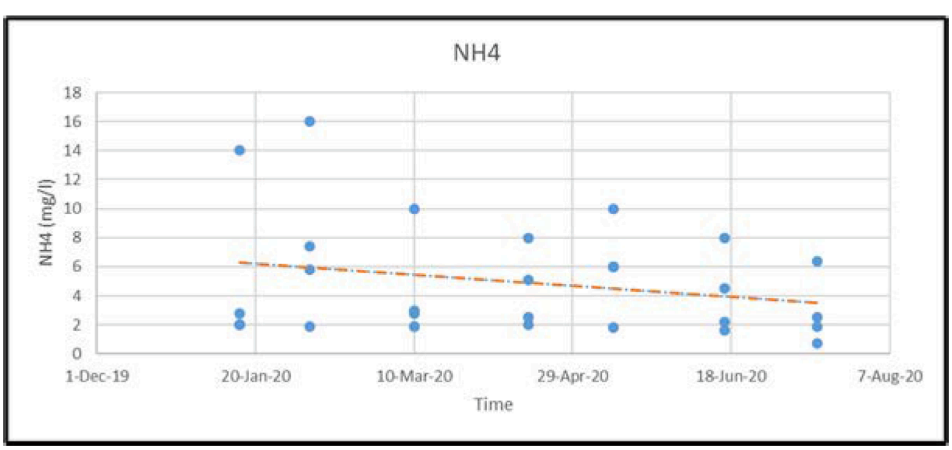

Fig. 8. Annual variations of NH_4 for year 2020 for Nashart drain.

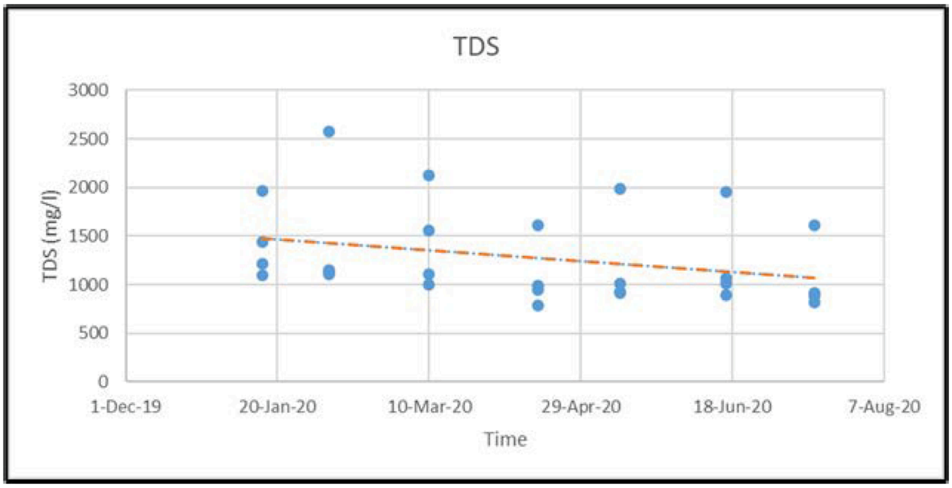

Fig. 9. Annual variations of TDS for year 2020 for Nashart drain.

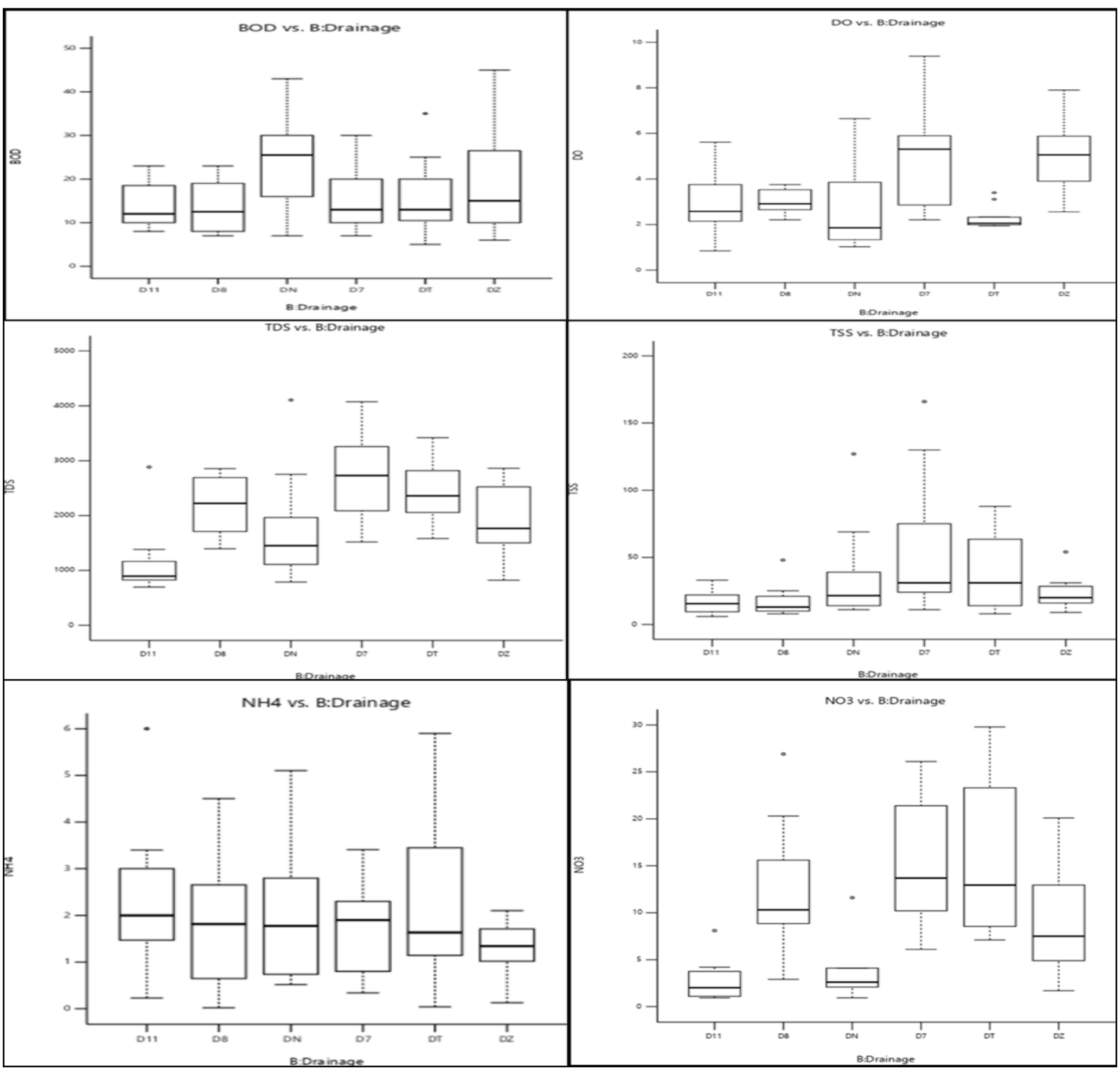

Fig. 10. Box plots for Mean values of water quality data in mg/l various the different studied drains.

wastewater (domestic, industrial, and agriculture). It also referred to the location of hotspots of study area which exceed the allowable limits of law48/1982 and WHO.

Comparing the output data of the used two statical methods, the Mean average method and ANOVA analysis, has been carried out. The Mean average method results indicate that the worst drains were Nashart drain, Drain 7 then Drain 11. While ANOVA shows that Nashart drain, drain 7 then Tira drain were the worst three drains.

ANOVA may be considered as a more reliable method compared to the Mean Average Method as it takes into consideration several factors such as year, water quality parameters, frequency of repeating the bad records. Moreover, ANOVA can also show the trend of results as a graphical representation and numerical equation.

The Chemical Pollution Index fluctuated through the study period for Nashart. It was observed that the concentrations have various trends because of the increase of the agricultural drainage discharge rate as well as the domestic wastewater. Also, the concentrations of all studied parameters have been increased during the period (January to April).

It was found that Nashart drain, Tira drain and drain 7 have the worst water quality conditions among the investigated six drains, with a recorded p-value less than 0.05 for all parameters. Therefore, it should be the priority in future rehabilitation and upgrading projects to improve its water quality condition.

Moreover, the adopted approach and techniques in this study can help the decision makers in setting the priorities for national rehabilitation projects for the agricultural drains in the study area as well as similar areas in Egypt.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Negm AM. Egyptian coastal lakes and wetlands. Part II Clim Change Biodivers 2019;49(0).

[2] Al-Afify ADG, Tahoun UM, Abdo MH. Water quality index and microbial assessment of Lake Qarun, El- Batts and El-Wadi Drains, Fayoum Province, Egypt. Egypt J Aquat Biol & Fish 2019;23(1):341–57.

[3] Al-Afify ADG, Abdo MH, Othman AA, et al. Water quality and microbiological assessment of Burullus Lake and its surrounding drains. Water Air Soil Pollut 2023; 234:385. https://doi.org/10.1007/s11270-023-06351-3.

[4] Bouida L, Rafatullah M, Kerrouche A, Qutob M, Alosaimi AM, Alorf HS, et al. A review on cadmium and lead contamination: Sources, fate, mechanism, health efects and remediation methods. Water 2022;14:3432. https://doi.org/10.3390/w14213432.

[5] El-Alfy MA, Darwish DH, El-Amier YA. Land use land cover of the Burullus Lake shoreline (Egypt) and health risk assessment of metal contaminated sediments, human and ecological risk assessment. Int J 2020. https://doi.org/10.1080/10807039.2020.1786667.

[6] El-Khayat HMM, Abd-Elkawy S, Ahmed MA, et al. Trends in genetic divergence among Biomphalaria alexandrina snails and Oreochromis niloticus fsh in response to water quality of Lake Burullus, Egypt. Egypt J Aquat Biol & Fish 2018;22(4): 25–47.

[7] Elsayed, F. A., Okbah, M. A., El-Syed, S. M., Eissa, M. A., & Goher, M. E. (2019). Nutrient salts and eutrophication assessment in Northern Delta lakes: Case study Burullus Lake, Egypt. Egyptian Journal of Aquatic Biology and Fisheries, 23(2), 145–163. https://doi.org/10.21608/ EJABF.2019.30239.

[8] Elshemy M, Zeidan B, Assar W. Water quality mitigation scenarios for Burullus Coastal Lake, Egypt. In Estuaries and coastal zones in times of global change. Springer; 2020. p. 89–110.

[9] Fishar MR, El-Damhogy KA, Mola HRA, Hegab MH, Abd ElHameed MS. Applying some biotic indices of macrobenthic invertebrates to assess water quality of Lake Manzala. Egypt Egypt J Aquat Biol & Fish 2015;19(2):29–41.

[10] GAFRD (2018). Fish production statistics of Egypt in 2016 (26th edition). General Authority for Fishery Resources Development. Ministry of agriculture, Cairo.

[11] Hany A, Akl F, Hagras M, Balah A. Assessment of recent rehabilitation projects' impact on water quality improvement in Lake Burullus. Egypt Ain Shams Eng J 2022;13:101492. https://doi.org/10.1016/j. asej.2021.05.006.

[12] Khalil, M. T. (2018). Physical and chemical properties of Egypt's coastal wetlands; Burullus wetland as a case study. In A. Negm, M. Bek, & S. Abdel-Fattah (Eds.) Egyptian coastal lakes and wetlands: part I. The handbook of environmental chemistry (Vol 71). Springer.

[13] Lee SW, Wendy W. Antibiogram and heavy metal resistance pattern of Salmonella spp. isolated from wild Asian sea bass (Lates calcarifer) from Tok Bali, Kelantan, Malaysia. Jordan. J Biol Sci 2011;4(3):125–8.

[14] Sayed MF, Abdel-Satar AM. Chemicals assessment of Wadi El-Rayan Lakes, Egypt. Am-Eurasian J Agric & Environ Sci 2009;5(1):53–62.

[15] Shaban, M., & Farag, H. (2018). Data driven water quality modeling for drain/ canal inflows to Lake Burull us. Ain Shams Engineering Journal, 9, 3197–3205. https://doi. org/10.1016/j.asej.2018.05.002.

[16] Sheta, B. M. (2019). Biodiversity and habitat use of wintering and breeding waterbirds in Burullus Lake (Ramsar site), Egypt. CATRINA, 19(1), 47–54. https://doi.org/10.21608/ CAT.2019.49179.

[17] Tiri A, Lahbari N, Boudoukha A. Assessment of the quality of water by hierarchical cluster and variance analyses of the Koudiat Medouar Watershed. Appl Water Sci, East Algeria 2015. https://doi.org/10.1007/s13201-014-0261-z.

[18] VishnuRadhan R, Zainudin Z, Sreekanth GB, et al. Temporal water quality response in an urban river: a case study in peninsular Malaysia. Appl Water Sci 2017;7: 923–33. https://doi.org/10.1007/s13201-015-0303-1.

[19] Yousry MM, El Gammal HAA. Factor analysis as a tool to identify water quality index parameters along the Nile River, Egypt. J Am Sci 2015;11(2):36–44.

[20] Zaghloul FA, Hosny S, Faragallah HM, et al. Preliminary assessment of water quality post-the first phase of the development plans in Lake Burullus, Deltaic coast of the Mediterranean Sea, Egypt. Sci Afr 2022;16:e01193.

Aya Mohamed, Ain Shams University graduate class of 2016 with excellent grade, I was ranked as the third of public works department and ninth of civil engineering department.

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Throughout my 7-years academic experience, I have gained valuable experience in delivering a wide range of topics and courses such as (Hydraulics, Geo informatics information, Civil drawing, management, planimetric surveying, Civil Engineering, Environmental and Sanitary, Highway and Transportation).

Not only that, but also, I've supervised a lot of students in their graduation projects and managed to guide them through their required tasks giving them assistance and provided evaluation and feedback for them on a weekly basis to put them on track. In addition, I was responsible for many administrative tasks such as developing civil engineering department regulations and preparing courses scheduled for teaching assistants (both full and part timers).

As for my research part, I've earned my master's degree from Ain Shams University with class honor producing two publications out of my thesis. And I am currently a doctoral candidate at Civil engineering department, Ain Shams University.