International Journal of Applied Engineering & Technology

ASSESSING THE ENVIRONMENTAL IMBACT OF AL-WARAR CANAL WATER POLLUTION BY EMBLOYING EPIPHYTIC DIATOMS AS BIOLOGICAL INDICATORS, RAMADI, IRAQ

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ABSTRACT
The study aims to use diatoms attached to the Ceratophyllum demersum L. plant as biological indicators to determine the environmental impact in the water of the Al-Warar Canal, east of the city of Ramadi, for the period from November 2022 to May 2023. Four sites were chosen, three of which were in the Al-Warar Canal and one site in the Euphrates River that feeds the canal via the Al-Warar Regulator. A set of physical and chemical parameters were measured in the water of the canal and the Euphrates River to study their relationship with the diversity and quantity of epiphytic diatoms cells adhered to the host aquatic plant, while examining the total number of fecal coliform bacteria colonies in order to employ these environmental factors in conducting the Canadian Water Quality Index (CCME – WQI) . The results of the current study showed that the water of the Al-Warar Canal suffers from the release of waste from human activities and sewage without treatment, and that most of the environmental factors studied indicate that it has exceeded the permissible limits and was described as hard and a high buffering capacity , with high values of electrical conductivity and total dissolved soled , with sufficient quantities available of nutrients with a high organic load. By employing the quantity and quality of diatoms cells, the quality of the canal water was estimated by conducting three biological indices, the results of which indicated that the water suffers from moderate pollution according to the Pollution Tolerance Index (PTI) , and that it is Misotrophic according to the Trophic Diatomic Index (TDI) , while it was described as having Less biodiversity according to the Shannon and wiener Index (H) . The results of the current study of the environmental factors studied were consistent with the results of biological indicators and the Canadian Water Quality Index (CCME – WQI) .

Keywords: Epiphytic Diatoms , Biological Indicators , CCME-WQI , Al-Warar Canal , Euphrates River .

INTRODUCTION
Al-Warar Canal is an artificial water canal that is considered one of the largest streams in Iraq. It branches off from the Euphrates River 500 meters from Ramadi Dam, east of the city of Ramadi, until it empties into Lake Habbaniyah, west of Baghdad. Al-Warar was dug in 1956 to reduce the waters of the Euphrates to avoid flooding and to store water in Lake Habbaniyah , to be used when the level of the Euphrates decreases . The length of the stream is 8 kilometers, and the passage of water to it is regulated through a dam that includes 24 gates , each opening is 6 meters wide. The canal's water suffers from poor quality due to the presence of many residential, industrial, and health complexes on its sides, where the waste of these complexes is thrown out of without treatment, in addition to the decrease in water levels during the current study period (Al-Anzy *et al* , 2023) . Benthic algae are a good biological indicators for estimating the water quality of aquatic ecosystems in comparison with phytoplankton, as benthic algae are distinguished by their ability to stabilize the ecosystem and prepare food for aquatic organisms, as they are stable and relatively stable in the aquatic environment (Blin & Herbst ,1998). Benthic algae are the main component of the food web (Stevenson, 1996). Non-diatomaceous algae have been used by many researchers as biological indicators for estimating water quality. They are considered less efficient than diatomaceous algae as biological indicators due to the great variation in their external forms, in the process of diagnosis, they also need to study their vegetative structures and may need to be grown in the laboratory (Pan, & Stevenson, 1999) . As for diatomaceous algae, they are good indicators for determining the health of aquatic ecosystems because they constitute the vast majority of the other classes of algae and are the primary food source for most invertebrates and fish (Al-Tamaki and Al-Obeidi, 2021) . Diatoms is also considered a biological monitor for changes occurring in aquatic systems, as it is widespread in most

different aquatic environments, and the ease of collecting samples and the duration of its life cycle is intermediate between bacteria and invertebrates, in addition to being sensitive to changes occurring in the conditions of water bodies and the degree of their pollution (Bellinger and Sigee , 2010) . The aim of the current study is to employ diatoms attached to *Ceratophyllum demersium* L . plants in the water of the Al-Warar Canal as biological indicators in determining water quality, while identifying the species of resistant and sensitive diatoms that indicate the nature of the organic and inorganic pollutants in the water of the Al-Warar Canal.

MATERIAL AND METHODS

Physical and chemical parameters analysis

Four sites were selected in the Warar Canal to collect water and Epiphytic algae samples attached to the *Ceratophyllum demersum* L. for a period November 2022 to May 2023 as shown in the map (1) and its geographical coordinates (Table . 1). Water temperature (WT) was measured using mercury thermometer while electrical conductivity (EC) was measured using electrical conductivity meter and pH using the field digital pH meter . While total dissolved soled (TDS) were measured using a multi-measured fieid digital device, and the turbidity was performed using a turbidity meter measurement device. According to APHA (2017) chloride(Cl) , sodium (Na) , total hardness (TH) , dissolved oxygen (DO) , biochemical oxygen demand (BOD) , nitrite (NO_2) , nitrate (NO_3) , and sulfate (SO_4) were conducted. Murphy and Reilly (1962) was based to determine phosphate(PO_4) concentrations. As for silicates(SiO_2) , he relied on Parsons (1984) to determine their concentrations in water samples.

Fecal coliform Bacteria

The membrane filtration method (WHO, 2008) was used to determine the total number of coliform bacteria to determine the quality of the canal water according to the Canadian Water Quality Index (CCME, 2007) . A nitrocellulose filter paper whose opening does not exceed 0.45 micrometers was placed in the designated place in the filtration unit. Transfer 100 ml of the sample to a container for the filtration unit, then the filter paper was transferred and placed on the surface of the hardened agar (FC- Agar) and the plate was left for a short time until the paper adhered to the nutrient media and this was evident by its red color on the back. Incubate the plate upside down at a temperature is 44.5 C^o for 24 hours, and the final result is recorded after 48 hours. Fecal coliform bacteria colonies were counted according to the equation below :

Total number of fecal coliform colonies / 100 ml = number of colonies x 100 / volume of sample

Collection and analysis of epiphytic diatoms

Samples of diatoms attached to *Ceratophyllum demersum* plants within the Al-Warar Canal were collected from four sites according to the method described in Hassan *et al.,*(2007). Permanent slides were prepared to count and characterize diatom cells (Barber, 1981). Diatoms cells were classified based on Patrik and Riemer (1966) and Germain (1981) . Diatoms cells were counted according to the method described in Martinez *et al.,* (1975) .

Biological indices

A set of biological indices was applied by employing the quality and relative density of diatom cells attached to the *Ceratophyllum demersum* plant in the sites of the current study, and its details are described below:

Pollution Tolerance Index (PTI) (Lang - Bertalot , 1979)

$$PTI = \Sigma\, ni * ti / N$$

Trophic Diatomic Index (TDI) (Kelly & Whitton , 1995)

$$WMS = \Sigma\, a\, s\, v / \Sigma\, a\, v$$

$$TDI = (WMS * 25) - 25$$

Shannon and Wiener Index (*H*) (Shannon and Wiener, 1949)

$H = \Sigma \text{Pi} \ \ln \text{Pi}$

Whereas :

ni = The number of individuals of a certain species of diatom.

ti = the tolerance of the particular species , which ranges from (1 to 4).

N = the total number of species in the sample.

a = Abundance of the species in the sample (number of individuals / total number)

s = sensitivity of the species to the nutritional status of water (from 1 to 5)

v= the amount of the type index (from 1 to 4).

Pi = number of individuals / total number of sample .

Water quality index

Through physical and chemical parameters , the Canadian Water Quality Index (CCME , 2007) was calculated based on the values exceeding the permissible limits locally and internationally and the number of samples on site, as detailed below:

$$CCME = 100 - \sqrt{F1 + F2 + F3} \ / \ 1.732 \qquad 5$$

Whereas:

F1 = (number of parameters that exceeded standard parameters / total number of measured parameters) x 100 .

F2 = (number of readings that exceeded standard parameters / total number of parameters measured) x 100 .

F3 = Total deviations / (0.01 / total deviations) – 0.01 .

Statistical analysis

The statistical program Statistical Analysis System - SAS (2018) was used to analyze the data to study the effect of sites on the studied traits, and the significant differences between the means were compared with the least significant difference (LSD) test.

RESULTS AND DISCUSSION

Physical and chemical parameters

Table (2) indicates the measured physical and chemical parameters and the values of the least significant differences (LSD) between the Al-Warar Canal water sites under the current study. The water temperature did not show a noticeable variation, which may be due to the close distance between these sites, as it recorded an average of about 22.5 C^o.There were no significant differences in pH values between the sites, which indicates that the canal water has a high Buffering capacity (Al-Anazy *et al* ., 2023), and its parameters ranged between 7.15- 7.60 . The turbidity and TDS values varied in their values, as the lowest averages 5.6 NTU and 223 mg/l respectively was recorded at Site 1 (Euphrates River), while all canal sites recorded values that exceeded the permissible limits (CCME , 2007) and the highest average was recorded 11.0 NTU at site 3 and 1343 mg/l at site 4 respectively , due to the canal water being affected by anthropogenic . The values of Cl and Na exceeded the permissible limits, although they varied between sites. This may be attributed to the decrease in the levels of the Euphrates River and the canal during the period of the current study (Al-Tamimi and Al-Obeidi , 2021), where the lowest rates were recorded at 145 and 192 mg/L, respectively, at site 1, while the highest rates were recorded at 228 and 273. mg/L , respectively. The electrical connection (EC) was affected by the pollution in the canal water as well as the decline in water levels, as it exceeded the permissible limits (WHO, 2008) and its values varied between sites, as the lowest rate was recorded at 1575 µ.s /cm in site 1 and the highest rate was

2235 µ.s /cm in site 4, which is characterized by low water levels. The water of the Al-Warar Canal was reported to be hard and exceeded the permissible limits, while the lowest rates were recorded at site 1 (Euphrates River) at 471 mg $CaCO_3$ / l , while the highest rate was recorded at 662 mg $CaCO_3$ / l . Human and industrial activities play a major role in increasing total hardness (TH) (Al-Tamaki and Al-Obeidi, 2023) . Sulfate (SO_4) concentrations recorded high values in the water of the canal and the Euphrates River, exceeding permissible limits, and did not record significant variation between sites , the lowest rate was recorded at site 1 at 397 mg/L, while the highest rate was recorded at 593 mg/L at site 4. The water of the Euphrates River is characterized by the availability of sulfates in high levels (Al-Tamimi and Al-Jumaily, 2021).

The canal and river waters are well aerated, and the dissolved oxygen values did not show a significant difference between the sites, as the lowest rate 5.4 mg / l was recorded in site 3 and the highest rate 6.0 mg / l was recorded in site 4. The availability of oxygen in the canal water may be attributed to dense growth of aquatic plants, which enhances dissolved oxygen in the water (Hassan *et al.,* 2020) . The values of the biochemical oxygen demand exceeded the permissible limits and their values did not differ significantly between the sites, as the lowest rate 9.8 mg / l at site 3 and the highest rate 13.0 at site 4 were recorded. These values confirm that the canal water is affected by human and industrial activities as a result of the release of sewage and industrial wastewater without treatment, which leads to an increase in the organic load of the water (Weiner, 2000).

Both nitrite (NO_2)) and nitrate (NO_3) did not exceed the permissible limits, and NO_2 concentrations did not show significant differences between the sites. Unlike NO_3, the lowest rates were recorded as 2.00 and 2.28 mg / l at sites 1 and 2, respectively, while the highest rates were recorded as 3.74 and 5.71 mg / l at sites 3 respectively. The high concentrations of nitrite and nitrate in the canal water compared to the water of the Euphrates River confirms that the canal water is affected by human , agricultural and industrial activities (EPA , 2002). Phosphate (PO_4) rates showed that they exceeded the permissible limits, and their values varied between sites, as the lowest rate 0.26 mg / l was recorded in site 4, while the highest rate 0.88 mg / l was recorded in site 1. The high concentrations of phosphate in the canal and the Euphrates River may be due to their influence on wastewater and agricultural activities (Hassan *et al* ., 2020). Silicates (SIO_2) are available in Iraqi waters (Hassan *et al*., 2020), as the current study showed that this element is available in all sites, and no significant variation appeared between the sites, as the lowest rate 4.80 mg / l was recorded in site 2, while the highest rate 5.86 mg / l was recorded in site 4.

Epiphytic diatoms analysis

Table (3) indicates the density and presence of diatom cells attached to the *Ceratophyllum demersum* plant at the sites of the current study, where 134 species were identified, including 8 species from order Centrales and 126 species belonging to the order pennales . This result was recorded in all sites, and it is a natural condition, given the environment and the presence of most pennate diatoms in the freshwater environment, in contrast to the centric diatoms (Al-Anzy and Al-Tamimi, 2023). He recorded a complete dominance of the presence and cell density of some diatoms in all locations, exceeding 10 (Cell x 10^3 / gm) , which is *Cyclotella meneghiana* , *Cocconeis placentula* , *C. placentula var. euglypta* , *C. placentula var. lineata and Syndra ulna* . While the presence and density of the rest of the species varied between sites.

BIOLOGICAL INDICES

Pollution Tolerance Index (PTI)

The values of the PTI varied between the seasons of the current study. The lowest rates were recorded in the summer 2.03 . High temperatures and low water levels play a major role in concentrating pollutants (Al-Tamimi and Al-Obeidi , 2021), while the highest seasonal rates 2.54 were recorded in the spring. This may be attributed to the rise in water levels, which leads to the dilution of pollutants (Hassan and Shaawiat 2015) (Figure 3), and the site variations of the values of PTI showed a noticeable variation, as the lowest rate 1.96 was recorded in site 1 and the highest rate 2.54 was recorded in site 3.

According to the results of the current study of the water of the Al-Warar Canal, it is considered moderately polluted (Table 4) (Lang - Bertalot , 1979), and these results were consistent with most of the physical and chemical factors measured. In the canal water, a number of species of epiphytic diatoms attached to the *Ceratophyllum demersum* plant have been identified, which are found in moderately polluted (middle tolerance water. They are: *Cocconeis placentula* , *Cyclotella meneghiniana* , *Fragilaria capucina* , *Synedra pulchella* and *Nitzschia frustulum* (Silva *et al* ., 2009) . These results were consistent with studies of the Euphrates River Basin (Al-Tamaki and Al-Obeidi, 2023; Al-Tamimi and Al-Jumaily, 2021) and other studies of Lake Al-Habbaniya (Al-Hasso and Al-Tamimi, 2022, Al-Anzy *et al.,* 2023*).*

Trophic Diatomic Index

The values of TDI varied seasonally, with the lowest rate of 38.5 recorded in the spring (Fig. 4) . This may be attributed to the rise in water levels and the dilution of pollutants, as Kelly and Whitton (1995) confirmed that water with poor nutrition (Oligotrophic) is clean, while rich water (Eutrophic) is polluted. The highest rate was recorded 52.6 in the autumn season . The values of TDI varied between the sites, as the lowest rate 31.9 was recorded in site 2, while the highest rate 65.2 was recorded in site 4. The distribution of benthic diet species varies depending on the sources of nutrients resulting from human and industrial pollution sources.

According to the results of the current study, the water of the Al-Warar Canal is considered to be Mesotrophic and moderate polluted water (Table 5) . A group of diatoms species have been identified that are attached to *Ceratophyllum demersium* plants and have moderate sensitivity to nutrients they are:: *Achnanthes affinis* , *Caloneis amphisdaena* , *Cocconeis placentula* , *C. subtilis* , *Cymbella pusilla* ,*C. tumida* , *C. ventricosa* , *Diatoma hiemale* , *Fragilaria capucina* , *F . intermedia* , *F. ulna* , *Gomphonema constrctum* , *G. gracile* , *G. subclavatum* , *Surirella ovalis* , *Syndra pulchella* , *S. ulna* . The results of the current study are consistent with many studies that used epiphytic diatoms attached to plants as vital evidence for estimating the trophic status of water and its quality (Al-Tamimi and Al-Obeidi, 2021: Al-Anzy *et al* ., , 2023).

Shannon and Weaner Index (*H*)

The seasonal variations of the Shannon index varied, as the lowest rate was recorded at 1.71 in the summer (Figure 5). This may be attributed to the decrease in water levels, the rise in temperature, and the increase in concentrations of pollutants resulting from human activities, which affects biodiversity (Lillis and 2000), while it was recorded the highest rate 2.56 is in the winter due to the dilution resulting from rising water levels. The locational variations in the values of *H* also varied, as the lowest rate of 1.88 was recorded at site 4 due to the decline in water levels in this site and its impact on sewage water and agricultural activities (Hassan and Shaawit, 2015), while the highest rate of 2.2 was recorded at site 1 (the Euphrates River).) Because it is not affected by the canal water, which encourages biodiversity in it. Most studies of the algae attached to the *Cyratophllum demersium* plant indicate that they are more diverse than other aquatic plants in order to increase the surface area of the plant, which encourages the growth and adhesion of algae to its surface (Al-Tamimi and Al-Obeidi, 2021).

According to the results of the current study, the waters of the Al-Warar Canal are considered to have low to moderate biodiversity and low to moderate pollution (Shanthala *et al* ., 2009) (Table 6) .

Water quality index

The Canadian Water Quality Index recorded low values for the water of the Al-Warar Canal, where the lowest value was recorded at 14.52 in Site 4, due to the exposure of the canal water to wastewater and agricultural activities, while the highest value was recorded at 40. 33 in the Euphrates River (site 1) (Figure 6). These results were expected with the results of the physical , chemical and Fecal coliform Bacteria tests, most of which exceeded the permissible limits . The total number of fecal coliform bacteria has a major role in influencing the results of the Canadian Water Quality Index (Al-Janabi *et al* ., 2012), as it recorded high values that mean ranged 4.13 - 19.94 colony x 10^3 / 100 ml due to the canal water being affected by untreated sewage. Therefore, Al-Warar canal water is of poor quality (Tables 7 and 8).The results of the current study were consistent with many studies on Iraqi water bodies, which showed that most of the water bodies are characterized by Fair to poor water quality (Abbas and Hassan, 2018: Meteeb *et al.,* 2023: Al-Anzi *et al* ., 2023).

CONCLUSIONS

Using epiphytic diatoms attached to the *Ceratophyllum demersum* plant as a vital guide to estimate the water quality of the Al-Warar Canal, which suffers from a heavy organic load with increasing human activities, is a helpful factor in predicting future changes in aquatic ecosystems. This is confirmed by the agreement of most of the environmental factors studied that exceeded the permissible limits with the results of the biological indicators and Canadian Water Quality index , which indicated that the water quality was moderate to poor.

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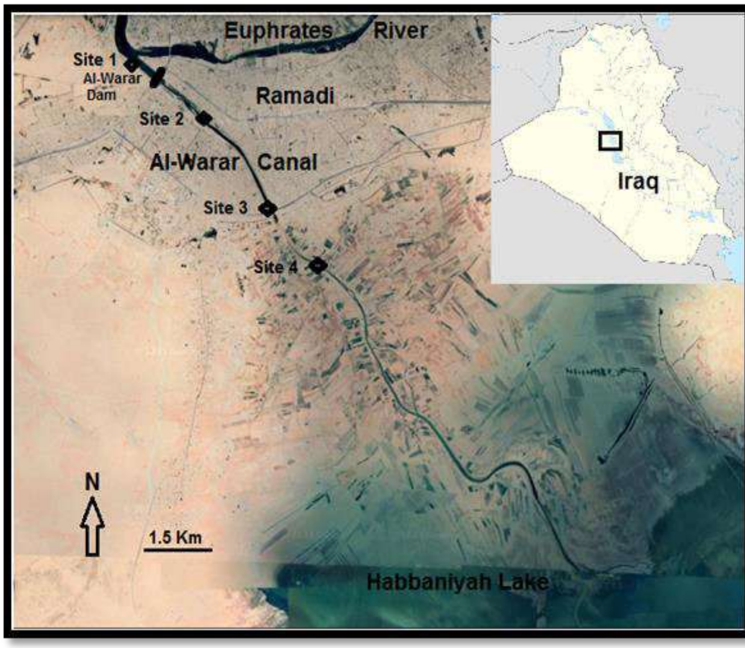

Figure 1. Map of sampling sites in Al-Warar Channel during the current study period . (google Earth)

Table 1. Geographic coordinates of sampling sites in the Al-Warar Canal . (Google Earth)

Sites	Latitudes (North)			Longitudes (East)		
	°	'	"	°	'	"
1 Euphrates River	**33**	**26**	**04**	**43**	**15**	**53**
2 Ramadi Women's Hospital	**33**	**26**	**25**	**43**	**16**	**47**
3 Al-Qasim Bridge	**33**	**25**	**09**	**43**	**17**	**15**
4 Hemerrah	**33**	**23**	**59**	**43**	**18**	**05**

Table 2. Range (up), means and standard deviation (Down) of physical and chemical parameters and numbers of Fecal coliform bacteria colonies in growth sites in the waters of the Al-Warar Canal during the current study period.

Parameters	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**LSD**
Water Temperature (C°)	12-33 22.5±12.3	12- 33 22.5±12.3	12- 33 22.5±12.3	22- 33 22.5±12.5	2.93 NS
pH	6.7 -7.8 7.3±0.47	7.4 - 7.7 7.6±0.13	7.2- 7.7 7.5±0.22	6.6 - 7.7 7.15±0.50	0.605 NS
Turbidity(NTU)	4.6 -6.5 5.6±0.18 b	4.4 -12.0 8.2±3.35 ab	7.0- 15.0 11.0±3.67 a	7.0 - 11.0 9.0±1.71 ab	5.022 *

Total Dissolved Solids(mg/l)	784 – 1062 923±5.12 b	908 – 1141 1024±23.50 b	1156 – 1316 1236±41.50 a	1168 – 1518 1343±36.25 a	176.85 *
Chloride (mg / l)	124-165 145±36.1 b	150-189 170±36.9 ab	186-201 194±20.9 ab	208-248 228±13.6 a	84.66 *
Sodium (mg/l)	151-232 192±17.6 b	178-255 217±19.1 ab	215-258 237±6.9 ab	258-288 273±16.4 a	63.75 *
Electrical Conductivity (µ.s/cm)	1189-1960 1575±324 c	1374 – 2048 1711±331 c	1748 - 2387 2068±281 b	1765-2705 2235±402 a	206.95 *
Total Hardness ($mg\ CaCO_3/l$)	448 -493 471±19.5 b	486 -569 528±35.0 ab	565 -617 591±23.5 ab	642- 681 662±18.7 a	117.47 *
Sulphate (mg/l)	378 -416 397±172	419 -496 458±32.5	462 -596 529±56.0	499 – 686 593±77.1	216.53 NS
Dissolved Oxygen (mg / l)	4.0-7.0 5.5±1.60	3.3-7.9 5.6±1.90	4.3-6.5 5.4±0.95	4.0-8.0 6.0±1.90	1.854 NS
Biochemical Oxygen Demand (mg/l)	9.0 -12.0 10.5±1.65	7.0 -14.0 10.5±3.01	8.5 -11.0 9.8±1.31	10.0 -15.5 13.0±2.33	4.589 NS
Nitrite (mg/l)	1.00 -3.00 2.00±0.97	0.35 -6.00 3.35±2.45	0.48 -7.00 3.74±2.75	0.46 -5.00 2.73±3.48	2.075 NS
Nitrate (mg/l)	0.75- 3.80 2.28±1.34 b	0.30 -6.50 3.40±2.83 ab	0.72-10.70 5.71±4.53 a	0.66 -5.1 2.88±1.97 b	2.671 *
Phosphate (mg/l)	0.05 -1.71 0.88±0.80 a	0.13 -0.38 0.26±0.12 b	0.14 -0.42 0.28±0.13 b	0.12 -0.51 0.31±0.18 b	0.478 *
Silicates (mg/l)	2.70 - 8.53 5.61±2.75	1.28 -8.33 4.80±3.27	2.61 -7.18 4.89±2.20	4.33 - 7.40 5.86±1.40	2.267 NS
FC (Colony*10^3/100 ml)	3.16-5.10 4.13±0.91 b	5.83-14.11 19.94±3.77 a	5.55-11.83 17.38±3.02 a	4.73-9.10 6.92±2.02 b	4.694 *
Averages with different letters within one row are morally different. * ($P < 0.01$), NS: Non significant . n =7					

Table . 3 Density and presence of epiphytic diatoms cells adhered to the *Ceratophyllum demersum* plant (Cell x 10^3 / gm) in the samples collection sites during the period of the current study.

Taxa	Site 1	Site 2	Site 3	Site 4
Class : BACILLROPHYCEAE				
Order: Centrales				
***Cyclotella comta*(Ehrenberg)Kutzing**	+ + +	-	+	+ +
***C.crassa* Wittrock**	-	-	+	+
***C.kuetzingiana* W.Smith**	-	-	+	+
***C.meneghiniana* Kutz.**	+ + +	+ + +	+ + +	+ + +
***C.ocellata* Pantocsek**	-	-	-	+
***Melosira granulate*(Ehr.)Ralfs**	+ + +	+ +	+ +	+
***M.italica*(Ehr.)kutz.**	+ + +	-	-	-
***M.varians* Agardh**	+ + +	+	+	+
Order: Pennales				
***Achnanthes affinis* Grunow**	-		+	
***Amphora normanii* Rabenhorst**	-	-	-	++
***Amphiprora ornata* Bailey**	+	-	-	-
***A.ovalis* Kutz.**	+ +	+	+	+
***Amphipleura rutilans* (Trentepohl ex Roth)Cleve**	-	-	+	-
***Bacillaria paxillifera* (Mull.)Hendy**	+ + +	+ + +	+ +	++ +
***Caloneis amphisbaena* (Bory)Cleve**	+ + +	-	+	-
***C. ladogensis* Cleve**	+	+ + +	-	-
***C. limosa* (Kutz.)Patrick**	-	-	+	-
***Cocconeis disculus* (Schumann)Cleve**	+ + +	+	++	++
***C. placentula* Ehren.**	+ + +	+ + +	+ + +	++ +
***C.placentula var. euglypta* (Ehren.)Cleve**	+ + +	+ + +	+ + +	+ + +
***C.plcentula var. lineata* (Ehren.)Van Heurck**	+ + +	+ + +	+ + +	+ + +
***C. subtilis* Schmidt**	+	-	-	-
***Cymbella affinis* Kutz**	+	+	+	+
***C.amphicephala* Nageli**	+	-	+	-
***C.aspera* (Ehren.)H.peragallo**	+ +	-	-	-
***C.cesati* Agardh**	-	-	+	-
***C.cuspidata* Kutz**	-	-	+	-
***C. cymbiformis* (Agardh)Kutz van Heurck**	-	+	-	-
***C.cymbiformis var cymbiformis* Agardh**	-	-	+	-
***C.differta* (Cleve-Euler)Krieger**	-	-	+	-
***C. helvetica* (Ehren)van Heurck**	-	-	-	+
***C. hustedtii* Krasske**	-	+	-	-
***C. microcephala* Grunow**	+	+ +	-	++
***C. minuta* Hilse**	-	+	-	-
***C. parva* (W.Smith)Kirchner**	+	+	+	+
***C. pusilla* Grunow**	+	-	+	-
***C. tumida* (Brebisson)van Heurck**	+ + +	+ + +	+	++ +
***C. ventricosa* Kutz**	+ +	+	+ + +	+ + +
Cymatopleura solea	-	+	-	-

***Denticula elegans* Kutz**	+	-	-	-
***Diatoma hiemale* (Lyngbye)Heiberg**	-	+ +	+	-
***D. vulgare* Bory**	+ + +	+	-	++ +
***Diploneis dalmatica*(Grunow)Cleve**	-	-	+	-
***D.ovalis* (Hilse)Cleve**	+	-	-	-
***D.placida* (Schmidt)Hustedt**	+	-	-	-
***Epithemia zebra* (Ehren)Kutz**	-	-	-	+
***Eunota formica* Ehren**	-	-	+	-
***Fragilaria capucina* Desmazieres**	+ +	-	-	-
***F. capitate* (Ehr)Lange-Bertalot**	-	-	-	+
***F.crotonensis* Kitton**	+ + +	-	+	+ + +
***F.intermedia* Grunow**	-	-	+	+
***F.pinnata* Ehren**	+	+	+ +	-
***F.pulchella* (Ralfs)Lange-Bertalot**	+ + +	-	+	-
***F.ulna* Nitzsch**	-	-	-	+ +
***Gomphonema constrictum* Ehren**	+ +	+ + +	+ +	+ +
***G.gracile* Ehren**	-	+	-	-
***G. helveticum* Brun**	-	-	+	-
***G. olivaceum* Lyngbye**	+ + +	+ +	+	-
***G. olivaceum var. olivaceum* (Lyngbye)Dezmazieres**	-	-	-	+
***G.parvulum* Kutz.**	-	-	+	-
***G.subclavatum* Grunow**	-	-	+ +	-
***Gyrosigma acuminatum* (Kutz.)Rabenhorst**	-	-	-	+ +
***Gyrosigma amphibia* kutz.**	-	+	-	-
***G.attenuatum* (Kutz.)Rabenhorst**	+ + +	-	+ + +	+
***G.distortum*(W.smith)Griffith&Henfery**	-	+	+	-
***G.nodiferum* (Grunow)Reimer**	+	-	-	-
***G.obscurum* W.Smith**	-	-	-	+
***G.spencerii* (W.Smith)Cleve**	-	-	-	+
***Navicula angelica* Ralfs**	-	-	+ + +	-
***N.bacillum* Ehren.**	-	-	-	+
***N.brevistriata* Grunow**	-	-	-	+ + +
***N.buccella* Hohn&Hellerman**	-	-	-	+
***N.canalis* R.M.Patrick**	-	-	+	+
***N.falaisiensis* Grunow**	-	-	-	+
***N.fragilarioides* Krasske**	+ + +	+ + +	+	+
N.faoensis	-	-	-	+
***N.frustulum* Hustedt**	+	-	-	-
***N.halophila* (Grunow)Cleve**	-	+	-	-
***N.minima* Grunow**	-	+ +	-	-
***N.monilifera* Cleve**	-	+	-	-
***N.notha* Wallace**	+ +	-	+	+ +
***N.parva* (Ehren.)Ralfs**	-	+	-	-
***N.pusilla* W.Smith**	+	-	-	-
***N.pupula* Kutz.**	-	-	+	-

***N.radiosa* Kutz.**	+	+ + +	+	+
***N.rhynchocephala* Kutz**	-	-	-	+
***N.simula* Patrick**	-	+ +	-	-
***N.soehrensis* Krasske**	-	+ + +	-	-
***N.schroeteri* Meisters**	-	-	+	-
***Nitzschia apiculate* (Gregory)Grunow**	-	+	-	-
***N.fasciculata* (Grunow)van Heurck**	-	+	-	-
***N.filiformis* (W.Smith)Hust**	+	+ +	-	+
***N.frustulum* (Kutzen.)Grunow**	-	+	-	-
***N.hantzschiana* Rabenhorst**	+ + +	+ + +	-	+ + +
***N.hungarica* Grunow**	+ +	+ +	+	+
***N.ignorata* Krasske**	+ +	+	-	-
***N.longissima* (Brebisson)Ralfs**	-	-	-	+
***N.obtusa* W.Smith**	+ +	+	+	+
***N.palea* (Kutz.)W.Smith**	+	+ +	-	-
***N.retusa* Lange-Bertalot&Bonik**	-	-	+	-
***N.romana* Grunow**	+ + +	+ + +	+ +	+ +
***N.sigma* (Kutz.)W.Smith**	+ + +	-	+	-
***N.sigma var.major* Grunow in van Heurck**	-	+ +	-	-
***N.sinuata* (Thwaites)Grunow**	-	+	-	-
***N.tryblionella* Hantzsch**	-	-	-	+
***N.tryblionella var. calida* Grunow**	+	-	-	-
***Pinnularia biceps* W.Gregory**	+	-	-	+
***P.borealis* Ehren.**	-	-	+ +	-
***P.braunii* (Grunow)Cleve**	-	-	-	+ +
***P.leptosoma* (Grunow)Cleve**	+	+	+	-
***P.major* (kutz.)Rabenhorst**	-	-	-	+
***P.simplex* Gandhi**	-	+ + +	-	-
***Pleurosigma angulatum* (Quekett)W.Smith**	-	+ +	+	+
***P.elongatum* W.Smith**	-	-	-	+ + +
***P.normanii* Ralfs**	+	-	-	-
***Rhopalodia gibberula* (Ehr.)Muller**	+	-	-	-
***R.gibba* (Ehr.)Muller**	-	+	-	-
***Rhoicosphenia curvata* (Kutz)Grunow**	-	-	+ + +	-
***Stauroneis anceps* Ehr.**	+	+	-	-
***Surirella ovalis* Brebisson**	-	-	-	+
***Syndra acus* Kutz.**	+ + +	-	+	-
***S.capitata* Ehr.**	+	-	-	-
***S.fasciculata* (Agardh)Kutz.**	-	-	-	+
***S.filiformis* Grunow**	-	-	+	-
***S.formosa* Hantzsch**	-	-	-	+ + +
***S.parasitica* (W.Smith)Husted**	+	-	-	-
***S.pulchella* Kutz.**	+	-	-	-
***S.rumpens* kutz.**	+ +	+	+ +	+ +
***S.tabulate* (Agardh)Kutz**	+	-	-	-
***S.ulna* (Nitzsch)Her.**	+ + +	+ + +	+ + +	+ + +
***S.ulna var.balatonis* (pantocsek)Cleve-**	-	-	-	+

Euler				
***S.ulna contracta* Ostrup**	-	-	+	-
***S.ulna var. logissima* (W.Smith)Brun**	+ +	-	-	-
***S.vaucheria* Kutz.**	+ + +	-	-	-

Notes : + (> 5 Cell x 10^3/gm) , ++ (5 – 10 Cell x 10^3) , +++ (< 10 Cell x 10^3)

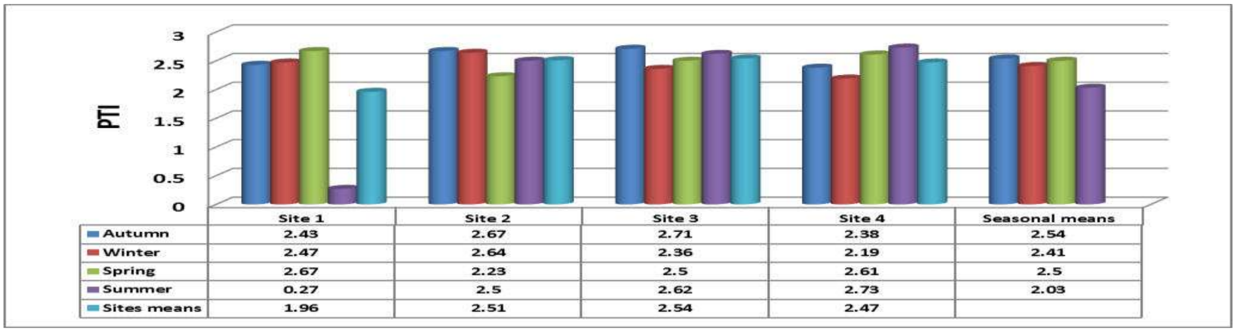

Figure 3. Seasonal and locational variations of Pollution Tolerance Index values in the water of the Al- Warar Canal during the period of the current study.

Table . 4 Values of Pollution tolerance index and degree of water pollution (Lang-Bertalot 1979).

PTI score	Quality and Water Pollution Degree
1	Most polluted water
2	Moderate polluted water
3	
4	Least polluted water

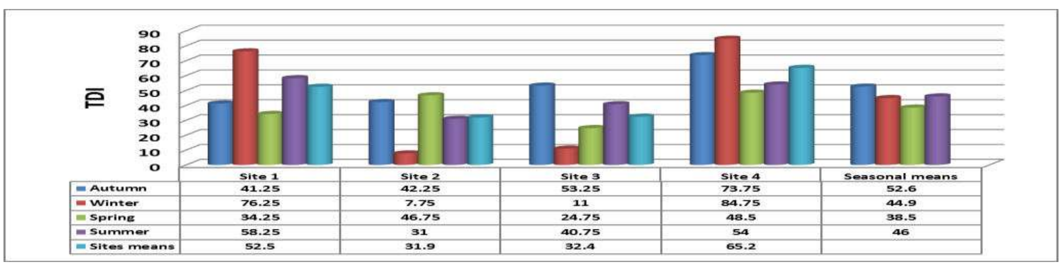

Figure 4. Seasonal and locational variations of Trophic Diatomic Index values in the water of the Al- Warar Canal during the period of the current study**.**

Table . 5. Evaluate the Trophic Diatomic Index and determine the degree of water quality (Kelly and Whitton , 1995).

TDI Score	Water Quality
< 35	Oligotrophic
35 - 50	Oligo – Mesotrophic
50 - 60	Mesotrophic
60 - 75	Eutrophic
> 75	Hypertrophic

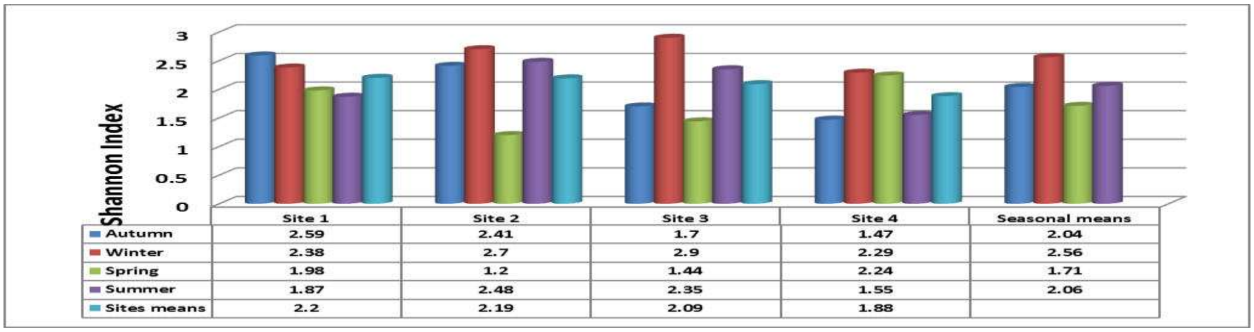

Figure 5. Seasonal and locational variations of Shannon and Waener Index values in the water of the Al- Warar Canal during the period of the current study .

Table 6 . The ranges of the Shannon index and its relationship to water pollution levels (Shanthala *et al* ., 2009)

Shannan Index Score	Diversity Level	Water Pollution Level
0.0 – 1.0	Very less	Heavy
1.0 – 2.0	Less	Moderate
2.0 – 3.0	Moderate	Light
3.0 – 4.5	High	Slight

Table . 7 Water quality classification according to the Canadian Water Quality Index (CCME , 2007).

Classification of Water quality	Water quality ranges	Degree
Excellent	100 - 95	1
Good	94 – 80	2
Fair	79 – 65	3
Marginal	64 – 45	4
Poor	44 – 0	5

Table 8. Canadian Water Quality Index (CCME-WQI) values extracted during the duration of the current study.

Sites	F1	F2	F3	CCWE-WQI	Classification of water quality
1	66.67	51.67	99.39	40.33	Poor
2	86.67	66.67	99.46	14.66	Poor
3	86.67	73.34	99.54	12.82	Poor
4	80.00	75.00	99.48	14.52	Poor

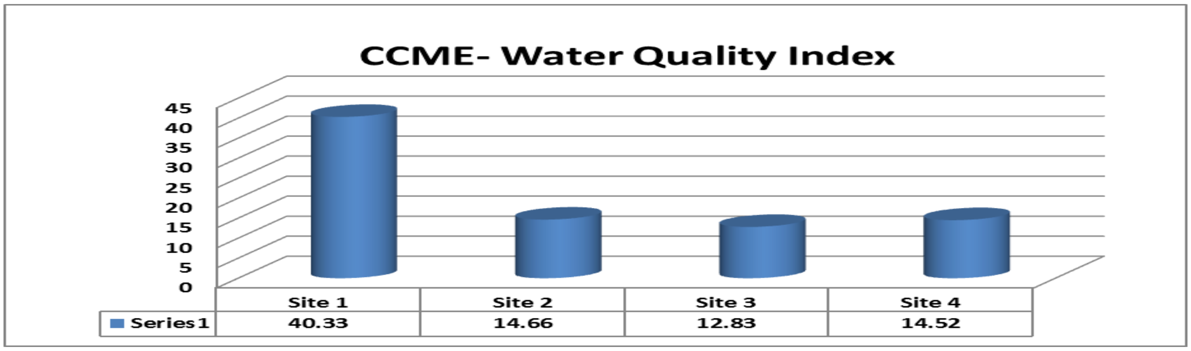

Figure 6 . Canadian Water Quality Index (CCME) values at the sampling sites for the Al- Warar Canal water during the current study period.