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Assessment of Water Suitability to Aquatic Life Using Some Water Physicochemical Variables and Water Quality Index

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ABSTRACT

This study was conducted at eight different sites along the Nile River. Various fishing areas, including islands, canals, and bridge areas suitable for fishing with small boats or traditional hooks, were investigated. This study determined whether these areas were suitable or not for aquatic life by assessing the physicochemical variables and water quality index (WQI) of the Nile River water. It is also possible to predict pollution in these areas by using these variables with the water quality index. The investigation was conducted between 2020 and 2021. The obtained values of physical and chemical variables of the Nile River water for the investigated sites were compared with the standard values for aquatic life published in the Canadian Water Quality Guidelines (2011). Based on the results, some variables examined had values that are higher than the recommended standards, affecting aquatic life in these areas. A higher concentration of physical and chemical parameters was observed during winter compared to summer. The COD/BOD ratio of the Nile River water in the investigated areas ranged from 3.89 in the summer season to 16.58 in winter. Its annual average was 10.24. The mean Mg2+ concentration in the investigated areas was 35.21mg/ l in winter and 31.26mg/ l in summer. NO_3 concentrations ranged from 61.12 to 724.58g/ l. The WQI was analyzed for 40 samples, of which 37.5% falls under grade B (good), 37.5% under grade C (poor), and 25% under grade D (very poor). The values of the WQI ranged from 34.34 to 96.63 in terms of compliance with guidelines for the protection of aquatic life. Assessment studies should be annually conducted to determine the water quality status of the Nile to improve its suitability for aquatic life.

INTRODUCTION

The River Nile is the most important freshwater resource for life and the main source of drinking and irrigation along the basin from its origin to its estuary in northern Egypt **(El-Sheekh *et al.*, 2017)**. Different types of pollution have been introduced into the Nile and its two branches (Damietta and Rashid), affecting its physical, chemical, and biological features. Waste products from industries, farms, and cities are some of these sources. Industrial wastewater is said to be the most important environmental pollutant, especially for drinking water. Advancements in industrialization, transportation technology, and agriculture play a crucial role in improving human standards of living, but these developments may also have an impact on the environment's air, water, and soil **(Sharaky *et al.*, 2017)**. Despite all the measures for pollution control, Egypt's Nile water is facing an increase in pollution sources. The three main sources of pollution are the discharge of domestic and industrial wastewater, return drainage of irrigated land, and flash floods into the Nile River. Furthermore, there are extensive challenges with iron, manganese, nitrate, and fecal coliform bacteria in the groundwater used for drinking water supply **(Shamrukh & Abdel-Wahab, 2011)**. Water quality, encompassing physicochemical and biological parameters, is crucial for maintaining the health of aquatic species and can act as a limiting factor **(Sharifinia, 2015; Yeganeh *et al.*, 2020)**. Water quality is defined as the suitability of water for different utilizations or operations **(Chapman & Chapman, 1996)**. The water content of organic and inorganic substances, along with its physical and chemical characteristics, are elements used to assess water quality **(Mapfumo *et al.*, 2002)**. The water quality index (WQI) is one of the most adapted tools for determining water quality. It combines physical, chemical, and biological parameters into a single value that ranges from 0 to 100. The concept of water quality index (WQI) was introduced by **Horton (1965)**, and since 1965, different water quality indices have been established by different organizations to assess water quality **(Chidiac *et al.*, 2023)**. Nevertheless, higher stocking densities, in combination with excessive inputs of feed, inevitably aggravate the regular water exchanges needed to maintain higher water quality **(Boyd, 2003)**. The CCME water quality index (CCME WQI) published by the Canadian council of ministers of the environment **(CEQG, 2011)** provides a comfortable tool to describe and judge complex water quality parameters data through merging three elements: 1. Scope (number of parameters not meeting water quality guidelines), 2. Frequency (number of times these guidelines are not met), and 3. Amplitude (amount by which the guidelines are not met), the index gives a number of ranges between 0 (bad water quality) and 100 (excellent water quality). These numbers are expressed into five categories to simplify its presentation **(CEQG, 2011)**. This study aimed to investigate some physicochemical parameters of the Nile River water in different areas (island, canals, and bridge area for fishing) to determine how suitable are these areas for aquatic life. Furthermore, the water quality index (WQI) was calculated for these areas to assess water quality and predict pollution.

MATERIALS AND METHODS

This study was not carried out on animals and thus did not require an ethical approval.

Study area

The River Nile is one of the world's longest rivers, with a total length of approximately 6700 kilometers, including approximately 1352 kilometers within Egypt. Fig. (1) illustrates the locations of eight areas of our study: (A) Al-Warraq Island (Bayen

Bahrain Island), (B) Al-Jazawiyah Canal, (C) The Ismailia Canal, (D) The Mariouteya Canal, (E) Al-Dahab Island, (F) The Al-Sharqawi Canal, (G) Al-Ayat Island, and (H) 15th May bridge area. Generally, it is used for fishing and watering.

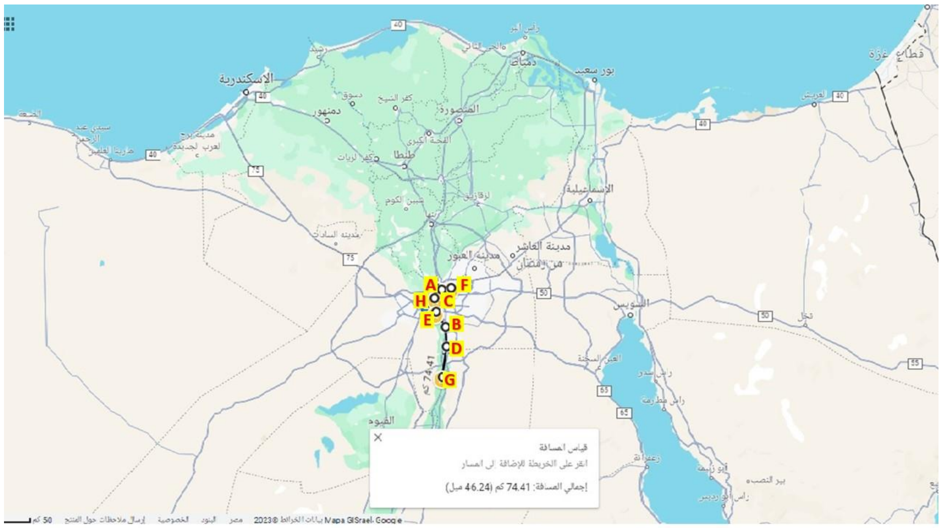

Fig. 1. Water sampling areas

Sample collection and physicochemical analysis of water

The samples were collected during the period of winter 2020 to summer 2021, with at least four to five samples collected per area per month and analyzed for this study. During the sampling process, polythene bottles were rinsed with distilled water before a water sample was taken from the subsurface water (about 30cm). We determined the physical and chemical characteristics of water samples, according to the American Public Health Association **(APHA, 1992; Al-Saffawi *et al.*, 2018)**. Upon arrival at the laboratory, the samples were kept at 4°C for chemical analysis. We measured the temperature and pH *in situ* using a calibrated handheld sensor (Hydrolab model Multi Set 430i WTW). The total solids (TS, mg/ l) were determined by evaporating a known weight of a well-mixed sample at 105°C. The total dissolved solids (TDS, mg/ l) were measured by passing a sample volume through a glass fiber filter (GF/ C) and evaporating a known weight of the filtrate at 105°C. TSS (Total suspended solids, mg/ l) is the difference between TS and TDS.

The dissolved oxygen (DO, mg/ l) values were regularly measured during sample collections and were determined by using a modified Winkler technique. Additionally, the chemical oxygen demand (COD, mg/ l) was performed via potassium permanganate technique. While, the biological oxygen demand (BOD, mg/ l) was assessed by using the 5 days incubation procedure, and the COD/ BOD ratio was calculated.

The major anion as chloride (Cl^-, mg/ l) was assessed via Mohr's technique. Moreover, the major cations include calcium (Ca^+ mg/ l) and magnesium (Mg^{2+} mg /l). The mgnesium was determined using a complex-metric technique via direct titration using EDTA solution.

The nutrient salts including ammonia (NH_3^- µg/l) was determined by the phenate method. The nitrite (NO2-, µg/ l) was detected using a colorimetric procedure by the formation of a reddish purple azo-dye. Additionally, the nitrate (NO_3^-, µg/l) was determined as nitrite after cadmium reduction.

Water quality index (WQI)

The water quality index was calculated based on the Canadian Environmental Quality Guidelines **(CEQG, 2011)** for aquatic life, published by the Canadian Council of Ministers of the Environment (CCME). The quality index provides a simple model for expressing water quality and plays a crucial role in water resource management. The index is based on the aggregate data on various water quality parameters at different times and places. It converts the data into a single value that provides information about that place at that particular time. In this study, the weighted arithmetic mean WQI was applied to determine WQI, following the method outlined by **(Horton, 1965)**. Eleven parameters were chosen for the calculation. Among them were pH, EC, TDS, DO, BOD, nitrate, total hardness, calcium, magnesium, chlorides, and alkalinity. We considered the season-wise mean values.

According to **Sudarshan *et al.* (2018)**, the calculation of the WQI using the weighted arithmetic mean approach involves three steps. The first step was to calculate the unit weights (Wi) for various parameters using the formula proposed by **Tiwari and Mishra (1985)**, where K = 1/∑ (1/S1 +1/S2 + S3 + ... +1/Sn). Secondly, the quality rating scale (Qi) for each parameter was determined using the formula: Qi = {(Qact-Qideal)/ (Sstd-Qideal)}*100. Finally, following a weighting analysis of the parameter and quality rating scale, the WQI was calculated using the formula: WAWQI =∑ WQ/∑Wi.

Statistical analysis

Statistical analysis was performed with SPSS version 16.0 software (SPSS Inc., Chicago, IL., USA). The data were expressed as means ± SD. The comparison of means was performed by one-way analysis of variance (ANOVA) followed by Student's t- test. A value of $P \leq 0.05$ was considered statistically significant.

RESULTS

Physical variables of investigated areas

The seasonal water temperature values of the Nile River at the investigated areas ranged between 15.8- 31.3°C (Tables 2, 6). During winter season, the highest value of temperature was (20°C) in area H, and the lowest value (15.8°C) was recorded in area A. The mean value recorded was 18.15°C, while during summer season, the highest value of temperature was found to be (31.3°C) in areas A and H, however the lowest value (28.8°C) was recorded for area C. Moreover, the mean value was 30.4°C. The overall annual mean value recorded for winter and summer was 24.275°C.

The TS value was found in the ranges of 432– 1167mg/ l (Tables 2, 6). Additionally, the highest values of TS (1167, 1092mg/ l) were recorded in area B during the winter and summer seasons, respectively. While, the lowest values (432, 498mg/ l) were recorded for area C during summer season and area H during winter season, respectively. The mean value of TS of the investigated areas was found to be 834.13mg/ l during winter, and 736.8mg/ l during summer season. Furthermore, the overall annual mean value of 785.465mg/ l was recorded.

The TDS value was found in the ranges of 189– 749mg/ l (Tables 2, 6). The highest values of TDS (749, 711mg/ l) were recorded in area B during the winter and summer seasons, respectively. While, the lowest values (189, 243mg/ l) were recorded for area H during summer and winter seasons, respectively. The mean value of TDS of investigated areas was found to be 456.25, and 366.5mg/ l during winter and summer seasons, respectively. The overall annual mean value was 411.375mg/ l.

The TSS value was found in the ranges of 228– 494mg/ l (Tables 2, 6). The highest values of TSS (494, 466mg/ l) were recorded in area F during the winter and summer seasons, respectively. While, the lowest values (228, 255mg/ l) were recorded for area C during summer season and area H during winter season, respectively. The mean value of TSS of investigated areas was found to be 377.88, and 370.30mg/ l during winter and summer seasons, respectively. The overall annual mean value was 374.09mg/ l.

Chemical variables of investigated areas

The obtained results of pH of the Nile River water in the investigated areas during winter (2020) and summer (2021) are displayed in Tables (2, 6). The pH value was found in the ranges of 7.17– 8.27. The highest values of pH (8.27, 7.96) were recorded in area H during the summer season and areas C and D during winter season, respectively. While, the lowest values (7.17, 7.26) were recorded for area A during summer season and area B during winter season, respectively. The mean value of pH of the investigated areas was found to be 7.60 and 7.70 during winter and summer seasons, respectively. The overall annual mean value was 7.65. The water DO concentration values were in the ranges of 4.7– 13mg/ l) (Tables 3,6) in the investigated areas. The highest values of DO concentration (13, 9.89mg/ l) were recorded in area H during the winter and summer seasons, respectively. While, the lowest values (4.7, 5.17mg/ l) were recorded for area B during winter and summer seasons, respectively. The mean value of DO concentration of investigated areas was found to be 8.86 and 7.78mg/ l during winter and summer season, respectively. Additionally, the overall annual mean value was 8.32mg/ l. The water COD concentration values were found in the ranges of 6.09- 63.73mg/ l (Tables 3, 6) in the investigated areas. The highest values of COD concentration (63.73, 16.89mg/ l) were recorded in area F during the winter and summer seasons, respectively. While, the lowest values (6.09, 13.93mg/ l) were recorded for area D during summer and winter seasons, respectively. The mean value of COD concentration of investigated areas was found to be 28.86 and 9.92mg/ l during winter and summer seasons, respectively. Furthermore, the overall annual mean value was 19.39mg/ l. The water BOD concentration values were found in the ranges of 0.77- 5.86mg/ l (Tables 3, 6) in the investigated areas. The highest values of BOD concentration (5.86, 5.02mg/ l) were recorded in area D during the winter season and area H during summer season, respectively. While, the lowest values (0.77, 1.38mg/ l) were recorded for area F during winter and summer seasons, respectively. The mean value of BOD concentration of investigated areas was found to be 3.81 and 3.54mg/ l during winter and summer seasons, respectively. Moreover, the overall annual mean value was 3.675mg/ l. The COD/ BOD ratios of the Nile River water in the investigated areas ranged between 3.89 during summer to 16.58 during winter with an annual average of 10.24.

Table 2. Some physical variables and pH of the Nile River water in the investigated areas during winter (2020) and summer (2021)

Areas / Variable	A	B	C	D	E	F	G	H	Mean
	During winter (2020)								
pH	7.28	7.26	7.96	7.96	7.61	7.39	7.66	7.50	7.60
Water T (^oC)	15.8	16.6	17.2	18.7	18.7	18. 8	19.4	20.0	18.15
TS (mg/l)	757	1167	702	553	1067	1145	784	498	834.13
TDS (mg/l)	417	749	325	275	584	651	406	243	456.25
TSS (mg/l)	340	418	377	278	483	494	378	255	377.88
During summer (2021)									
PH	7.17	7.57	7.66	7.90	7.79	7.36	7.9	8.27	7.70
Water T(^oC)	31.3	28.9	28.8	30.6	30.5	31.1	30.5	31.3	30.4
TS (mg/l)	512	1092	432	472	886	998	899	603	736.8
TDS (mg/l)	213	711	204	176	471	532	436	189	366.5
TSS (mg/l)	299	381	228	296	415	466	463	414	370.3

Table 3. Chemical variables (Oxygen forms) of the Nile River water for areas investigated during winter (2020) and summer (2021)

Areas / Variable	A	B	C	D	E	F	G	H	Mean
	During winter (2020)								
DO (mg/l)	8.7	4.7	10.5	10.7	7.5	6.3	9.5	13.0	8.86
COD (mg/l)	28.73	23.33	33.69	13.93	29.09	63.73	18.8	19.6	28.86
BOD (mg/l)	4.1	1.27	4.97	5.86	4.1	0.77	4.20	5.18	3.81
COD/ BOD	7	18.37	6.78	2.38	7.09	82.77	4.47	3.79	
Total	132 / 8 =16.58 COD / BOD ratio (16.58:1)								
	During summer (2021)								
DO (mg/l)	7.49	5.17	8.30	9.69	7.45	6.5	7.77	9.89	7.78
COD (mg/l)	9.17	7.77	11.05	6.09	11.85	16.89	10.3	6.25	9.92
BOD (mg/l)	3.33	1.41	4.46	4.83	3.69	1.38	4.22	5.02	3.54
COD/ BOD	2.75	5.51	2.48	1.26	3.21	12.24	2.44	1.25	
Total	31.14 / 8 = 3.89 COD / BOD ratio (3.89:1)								

Water Cl^- concentration was found in the ranges of 26.95– 197mg/l (Tables 4, 6). The highest values of Cl^- (197, 184.35mg/ l) were recorded in area F during the winter and summer seasons, respectively. While, the lowest values (26.95, 34.18mg/ l) were recorded for area H during summer and winter seasons, respectively. The mean value of Cl^- concentration of investigated areas was found to be 76.49 and 90.06mg/ l during winter and summer season, respectively. The overall annual mean value was 83.275mg/ l. The water Ca^{+2} values were fluctuated in the ranges of 22.45– 53.46mg/ l (Tables 4, 6) for water in the investigated areas. The highest values of Ca^{2+} concentration (53.46, 48.08mg/ l) were recorded in area B and area E during the winter and summer seasons, respectively. While, the lowest values (22.45, 37.4mg/ l) were recorded for area B and area D during summer and winter seasons, respectively. The mean value of Ca2+ concentration for the investigated areas was found to be 45.77 and 34.88mg/ l during winter and summer season, respectively. Moreover, the overall annual mean value was 40.325mg/ l. The Mg2+ values were fluctuated in the ranges of 12.65– 92.42mg/ l (Tables 5, 7) for water in the investigated areas. The highest values of Mg2+ concentration (92.42, 66.47mg/ l) were recorded in area B during the summer and winter seasons, respectively. While, the lowest values (12.65, 20.82mg/ l) were recorded for area A & H during summer and area D during winter season. The mean value of Mg2+ concentration of investigated areas was found to be 35.21 and 31.26mg/ l during winter and summer seasons, respectively. Furthermore, the overall annual mean value was 33.235mg/ l.

Table 4. Chemical variables [(Major Anions / Cl-) and (Major Cations / Ca2+ & Mg2+)] of the River Nile water in the investigated areas during winter (2020) and summer (2021)

Areas / Variable	A	B	C	D	E	F	G	H	Mean
	During winter (2020)								
Cl^- (mg/l)	41.98	161.8	41.13	49.64	40.56	197.2	45.39	34.18	76.49
Ca^{2+} (mg/l)	48.58	53.46	45.05	37.04	52.05	38.64	53.1	38.2	45.77
Mg^{2+} (mg/l)	34.83	66.47	34.25	20.82	25.11	45.73	33.2	21.3	35.21
T-Hardness(mg/l)	266	407	254	179	234	286	270	184	260
	During summer (2021)								
Cl^- (mg/l)	45.38	181.60	43.96	28.37	112.02	184.3	97.85	26.95	90.06
Ca^{2+} (mg/l)	35.28	22.45	25.66	28.90	48.08	43.29	44.89	30.47	34.88
Mg^{2+} (mg/l)	12.65	92.42	17.52	15.60	35.99	27.24	36.00	12.65	31.26
T-Hardness(mg/l)	141	437	137	141	269	221	261	129	217

The concentration levels of NH_3 were found in the ranges of 209– 6253.3µg/ l (Tables 5, 6) for water in the investigated areas. The highest values of NH_3 concentration level (6253.3, 1944µg/ l) were recorded in area E during winter season and area D during summer season, respectively. While, the lowest values (209, 593.4µg/ l) were recorded for area H during summer and winter seasons, respectively. The mean value of NH3-concentration level for the investigated areas was found to be 4310.3 and 3522.8µg/ l during winter and summer seasons, respectively. Furthermore, the overall annual mean value was 3916.6µg/ l.

The concentration levels of NO_2 were found in the ranges of 20.4– 71.75µg/ l (Tables 5, 6) for water in the investigated areas. The highest values of NO_2 concentration level (71.75, 68.90µg/ l) were recorded in area A during the summer and winter seasons, respectively. While, the lowest values (20.4, 32.15µg/ l) were recorded for area G during winter season and area H during summer season, respectively. The mean value of NO_2 concentration level of the investigated areas was found to be 35.66 and 49.56µg/ l during winter and summer seasons, respectively. Moreover, the overall annual mean value was 42.61µg/ l. The concentration levels of NO_3 were found in the ranges of 61.12– 724.58µg/ l (Tables 5, 6) for water in the investigated areas. The highest values of NO_3 concentration level (724.58, 578.6µg/ l) were recorded in area A during the summer and winter seasons, respectively. While, the lowest values (61.12, 64.65µg/ l) were recorded for area E during winter season and area C during summer season, respectively. The mean value of NO_3 concentration level of investigated areas was found to be 187.41 and 226.02µg/ l during winter and summer seasons, respectively. The overall annual mean value was 206.715µg/ l.

Table 5. Chemical variables (Nutrient salts) of the Nile River water in the investigated areas during winter (2020) and summer (2021)

Variable \ Areas	A	B	C	D	E	F	G	H	Mean
	During winter (2020)								
NH_3^- (µg/l)	5976.5	4637.2	3732.2	3004.7	6253.3	4751.7	5533.0	593.4	4310.3
NO_2 (µg/l)	68.90	31.87	28.25	24.86	29.13	56.64	20.4	25.2	35.66
NO_3 (µg/l)	578.6	79.90	38.95	274.9	61.12	110.1	108.0	247.7	187.41
	During summer (2021)								
NH_3^- (µg/l)	5286	4394	3194	1944	4869	4151	4135	209	3522.8
NO_2 (µg/l)	71.75	53.35	59.77	34.38	42.96	65.77	36.32	32.15	49.56
NO_3 (µg/l)	724.58	94.72	64.65	324.75	83.55	127.52	139.49	248.86	226.02

Table 6. The comparison between the mean values of water physical and chemical variables for the investigated areas and for aquatic life (CEQG, 2011)

Variable	Winter	Summer	Mean ± Sd.	Aquatic life (CEQG, 2011)
Physical variables				
pH	7.60	7.70	7.65 ± 0.07	6.5 – 9
Water T (°C)	18.15	30.4	24.275 ± 8.66	8 – 28
TS (mg/l)	834.13	736.8	785.465 ± 68.82	
TDS (mg/l)	456.25	366.5	411.375 ± 63.46	500
TSS (mg/l)	377.88	370.3	374.09 ± 5.36	+250
Chemical variables (Oxygen forms)				
DO (mg/l)	8.86	7.78	8.32 ± 0.76	5.5
COD (mg/l)	28.86	9.92	19.39 ± 13.39	7
BOD (mg/l)	3.81	3.54	3.675 ± 0.19	5
Chemical variables (Major anions and cations)				
Cl^- (mg/l)	76.49	90.06	83.275 ± 9.60	120
Ca^{2+} (mg/l)	45.77	34.88	40.325 ± 7.70	
Mg^{2+} (mg/l)	35.21	31.26	33.235 ± 2.79	
Total hardness (mg/l)	260	217	238.5 ± 30.41	500
Chemical variables (Nutrient salts)				
NH_3 (µg/l)	4310.3	3522.8	3916.6 ± 556.92	1370
NO_2 (µg/l)	35.66	49.56	42.61 ± 9.83	60
NO_3 (µg/l)	187.41	226.02	206.715 ± 27.30	2930

Water quality index (WQI)

The calculation of WQI of water samples in the investigated areas is presented in Table (7). A total of 40 samples were analyzed for WQI, with 37.5 % of the samples falling under grade B (good), 37.5 % of the samples under grade C (poor), and 25 % of the samples under grade D (very poor). WQI values ranged from 34.34 to 96.63, according to the guidelines for the protection of aquatic life. These results are exhibited in

Table (9) and Fig. (1). The good water quality rating (Grading B) was detected in areas C, D and H. The poor water quality rating (Grading C) was detected in areas A, E and G. While, the very poor water quality rating (Grading D) was detected in areas B and F.

Table 1. Water quality rating (WQR) as weight arithmetic WQI method

Water quality index (WQI)	Water quality rating (WQR)	Grading
0 – 25	Excellent	A
26 -50	Good	B
51 – 75	Poor	C
76 – 100	Very Poor	D
Above 100	Unsuitable for drinking	E

Table 7. Water quality index (WQI), water quality rating (WQR), and grading of the investigated areas

Area	A	B	C	D	E	F	G	H
WQI	51.71	81.08	34.34	36.50	57.71	95.63	65.5	42.13
WQR	poor	very poor	good	Good	poor	very poor	Poor	good
Grading	C	D	B	B	C	D	C	B

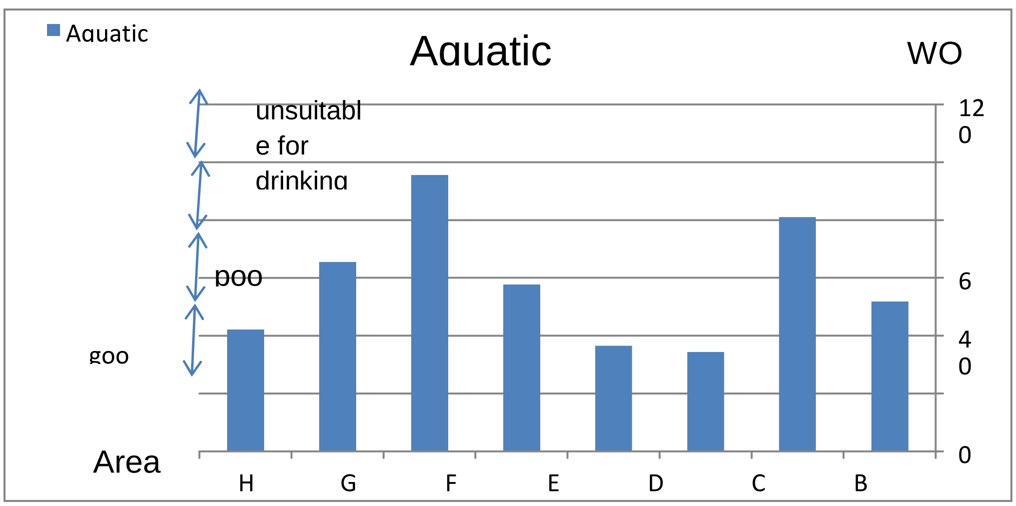

Fig. 2. Quality of water of the Nile River in the investigated areas using water quality index (WQI)

DISCUSSION

Temperature is a key factor affecting the growth and life cycles of most aquatic creatures influencing all physical, chemical, and biological processes in the aquatic environments. In general, as water temperature increases, the rate of chemical reactions increases, leading to a decrease in the dissolved oxygen values, as oxygen readily dissolves in cold water than in the warm water. Factors such as pH and alkalinity are also affected **(Murdoch, 1991; Sharaky *et al.*, 2017)**.

The increase of the water temperature is related to the increase of the ambient temperature, moreover the solid particles floating on the water can absorb heat and emit it again to the surrounding water medium **(Awadallah *et al.*, 1991)**.

The general annual average of temperature in the current study (24– 27.5^{o}C) meets the guidelines of **CEQG (2011)** for aquatic life (8– 28^{o}C). Furthermore, the results are in accordance with those of **Mousad et *al.* (2020)** and **Abdo *et al.* (2022)**. The previos authors stated that, the mean of the water temperature of the Nile River decreased during winter season and increased during the summer season, with no differences observed in water temperature values between the examined areas. In addition, no obvious thermal stratification was recorded in the investigated areas, possibly due to the shallowness of the water in these areas (The average depth of the Nile River is between 8- 11m).

The total dissolved solids (TDS) are the solids that remain in water after filtration, if the dissolved solids in the water exceed 300mg/ l, they adversely affect aquatic organisms. The total dissolved salts along the Nile River were less than 450mg/ l and there was no restriction on using it for some susceptible crops **(Ayers & Westcot, 1985)**. The total suspended solids (TSS) are particulate (organic or inorganic) substances, which afterward are deposited as a bottom sediment **(El-Nady & Dowidar, 1997)**. The Nile River is higher in concentration of total major ions (TDS) relative to the major rivers and lakes of the world due to the long distance of the Nile flow to the Mediterranean Sea, and the abundance of the basaltic source rock in Ethiopian Highlands **(Sharaky *et al.*, 2017)**.

Our results indicate that the general annual average of TDS (411.375mg/ l) is below the guidelines outlined byo **CEQG (2011)** for aquatic life (500mg/ l). The increasing in (TS, TDS, and TSS) values during winter season may be attributed the decrease in water level. On the contrary, in the summer, the rising of water levels results in a dilution of the solids and a decrease in their concentration. These results coincide with the reports published by **Authman and Abbas (2007)** and **Abdo *et al.* (2022)**.

The Nile water is used to be alkaline and predominantly of the bicarbonate type **(Rifaat *et al.*, 2019)**. Generally, natural water streams have pH ranging between 6 and 8.5 **(WHO, 1993)**. The favorable pH for aquaculture production is between 6.5- 9.0. Additionally, the severe fluctuation of pH of the water may cause a harmful or even lethal effect to aquatic organisms **(Murdoch, 1991)**. The water pH values are quite variable throughout the seasons; the increase of pH values in the Nile water is a result of photosynthesis and plant or phytoplankton growth **(WHO, 1993)**. This increase promotes the precipitation of metals, which subsequently settle on the river bottoms and result in reduced water column **(Forstner & Wittmann, 1983)**. Furthermore, the increase in pH above the normal range (6- 9) elevates the toxicity effect of ammonia on most fish spp.

Lower pH may be attributed to the decay of phytoplankton and organic impurities that reach water from municipal or agricultural contamination, leading to formation of organic acids and other breakdown products **(Chapman, 1992; Elewa & Ghallab, 2000; Abdo, 2013)**. The general annual average of pH recorded in our results (7.65) is within the permissible limits of **CEQG (2011)** for aquatic life (6.5- 9).

Oxygen is a limiting factor for life and growth in the aquatic system. Atmospheric oxygen is transferred to the water across the air-water interface **(Smith, 1990)**. The phytoplankton and aquatic plants use water carbon dioxide during the photosynthesis reaction in order to produce simple sugar (glucose); moreover, oxygen is produced as side to product this reaction. Dissolved oxygen (DO) is the level of free, non-compound oxygen present in water or other liquids; stress occurs when DO levels drop below 5.0mg/ l. Fish death can occur when oxygen levels remain below 1– 2mg/ l for a few hours **(Best *et al.*, 2007)**. Concertation of dissolved oxygen in the water depends on the water temperature, salinity, and pressure. It is worthy to mention that, cold water holds more oxygen than warm water; also freshwater contains more oxygen than saltwater or brackish water. The amount of oxygen dissolved in water decreases as altitude increases due to the decrease in relative pressure **(Smith, 1990)**. The decrease of DO may be attributed to the consumption of DO by respiration of phytoplankton, aquatic plants, fish, bacteria, and decay of the organic contaminants as agricultural or municipal wastes **(Cole, 1979)**.

The chemical oxygen demand (COD) is commonly used to indirectly measure the amount of organic compounds in water **(Peavy *et al.*, 1986)**, while biological oxygen demand (BOD) is the amount of oxygen consumed by bacteria during the decomposition of organic or inorganic materials. Good quality and unpolluted water must contain BOD of 5mg/ L or less **(Murdoch, 1991)**. Our results reveal that the general annual average of DO (8.32mg/ l) and COD (19.39mg/ l) are above the permissible limits of **CEQG, (2011)** for aquatic life (5.5, 7mg/ l), respectively. On the other hand, the general annual average of BOD (3.675) is below the permissible limits of **CEQG (2011)** for aquatic life (5mg/ l).

Pure water always shows 1: 1 COD/ BOD ratio, while raw domestic waste water displays 2: 1 to 4: 1 ratio. A high COD/ BOD ratio indicates high organic matter that is not broken down by microorganisms; these closer values, especially during the summer season, show that the structures of organic matter entering the Nile River water in the investigated areas are similar approximately in all studied areas except the areas F and B during winter season. Our results are in accordance with those of **Al Afify *et al.* (2019)**, **Mohamed *et al.* (2019)** and **Masoud *et al.* (2020)**.

The chloride, bromide, and iodide are conservative water constituents and can be used for the mixing calculations and for the identification of the water origin, with less ambiguity than other dissolved species **(Trettin *et al.*, 1999)**. Excessive chloride concentration increases corrosion rates of metals, as well asincreasing the concentration of metals in the drinking water **(WHO, 2002)**. Our results indicate that the general annual average of chloride (83.275) is below the permissible limits of **CEQG (2011)** for aquatic life (120mg/ l). Our results concurwith those of **Mohamed and Mohamed (2005)** and **Authman and Abbas (2007)**.

The Nile River calcium content is probably derived from the Ca-bearing rocks (Eocene and Late Cretaceous limestone and minor gypsum rocks of the Western Desert, **(Said, 1981)**. The hardness of water is the traditional measure of the capacity of water to react with soap. It depends mainly on the presence of dissolved calcium and magnesium salts. The total content of these salts is known as general hardness, which can be further divided into carbonate hardness, and non-carbonate hardness **(Chapman, 1992)**. The current results indicate that the general annual average of total hardness (238.5mg/ l) is below the permissible limits of **CEQG (2011)** for aquatic life (500mg/ l). Finally, from the overall mean values of cations during winter and summer season [Ca^{2+} (40.325mg/ l) - Mg^{2+} (33. 235mg/ l)], the predominant cations trend was in the order of $Ca^{2+} > Mg^{2+}$. These results are consistent with those reported by **Abdel-Satar *et al.* (2010)**, **Abou El-Gheit *et al.* (2012)**, **Sharaky *et al.* (2017)** and **Abdo *et al.* (2022)**.

Remarkably, aquatic ecosystems often receive waste water discharges from a variety of industrial, municipal, agricultural, and other sources. Approach to manage this liquid wastes is premised on the assumption that the receiving water systems have some capacity to assimilate anthropogenic wastes without adversely affecting designated water uses **(CCME, 2003)**. The nitrite (NO_2), nitrate (NO_3), and ammonia (NH_3) are essential in the productivity of the aquatic ecosystems **(Abdo, 2002)**. The determination of nitrate and nitrite in rivers gives a general indication of the nutrient status and level of organic pollution. In Egypt, risks mainly arise from the unsecure conventional systems for sewage disposal in villages (latrines and septic tanks), and seepage or runoff of irrigation water containing nitrogen fertilizers to the Nile River **(Grischek & Bartak, 2016)**. The denitrifying bacteria and the biological uptake are responsible for the decrease of nitrate along the Nile River **(Sharaky *et al.*, 2017)**. Notably, nitrite is an intermediate product of the aerobic Nitrosomonas bacteria that merges oxygen and ammonia. Generally, these nutrient salts are responsible for the eutrophication **(Abdo, 2002; Badr *et al.*, 2013)**.

Our results determine that the general annual average of NH_3 (3916µg/ l) is above the permissible limits of **CEQG (2011)** for aquatic life (1370µg/ l). On the other hand, the results in Table (8) indicate that the general annual average of NO_2 (42.61µg/ l) and NO_3 (206.715µg/ l) are below the permissible limits of **CEQG (2011)** for aquatic life (60, 2930µg/ l), respectively. This increase would affect the aquatic environment in this area. Our results are parallel to those recorded by **Abdo (2002)**, **Badr *et al.* (2013)**, **El-Sayed and Salem (2015)**, **Al-Afify *et al.* (2019)** and **Abdo *et al.* (2022)**.

In addition, water quality index (WQI) is a very effective tool for communicating water quality information to citizens and decision-makers **(Sukumaran *et al.*, 2015; Al-Saffawi & Al-Sardar, 2018)**. In Egypt, from December to January, irrigation canals under maintenance (winter closure) and the water released from the Aswan Dam is reduced, therefore less dilution of sewage inputs occur **(HCWW, 2018)**. The water quality deteriorates in the downstream direction due to the disposal of municipal and industrial effluents, inflow of agricultural drainage, as well as the decrease in the water flow **(Rifaat *et al.* 2019)**. **Radwan (2005)** in his study calculated the water quality index for the Nile River, and the results revealed that DO, NO_3, and BOD varied from good to excellent. Another study was carried out by **Abdo *et al.* (2022)** to assess the water quality index (WQI) for the Rosetta branch water and 3 drains (El-Rahawy, El-Soble and El-Gezira) during winter of 2017 to summer of 2018. The study deduced that the mean annual averages of WQI values of Rosetta branch water ranged from poor to very poor for aquatic life (up to 97) in stations exposed to wastewater discharged from drains into water branch.

During the present study, areas B and F which are located in the front of drains (points of discharging) recorded a very poor water quality with grade (D), while areas A, E, and G exhibited a very poor water quality with grade (C), but with less pollution rate in areas B and F. On the other hand, areas C, D, and H which are located far from the points of discharging registered a good quality water with grade (B). Moreover, the present results showed that the water quality index (WQI) values of the Nile River water in the investigated areas ranged between (34.34– 96.63). The higher WQI values of poor or very poor water quality are mainly resulted from the discharges of one or more drains, without any convenient treatment before discharging. These results are in accordance with those reported by **Ezzat *et al.* (2012)**, **El-Sheekh (2017)**, **Al-Saffawi and Al-Sardar (2018)**, **HCWW (2018)**, **Rifaat *et al.* (2019)**, **Abdo *et al.* (2022)** and **Khalefa *et al.* (2022)**.

CONCLUSION

- The WQI values revealed that the Nile River water in areas recorded poor or very poor is located at the point or near drains discharges (general or sporadic discharges).

- The three major sources of the Nile water pollution in the study areas are industry, agriculture, and household waste.
- The decrease in water level (during winter season); dilution rate increases in water level (during summer season) of the investigated areas; water and climatic conditions are the most important factors affecting the physical and chemical characteristics of the water of these areas.
- In general, the Nile water is suitable for aquatic life in some investigated areas and unsuitable in other areas. Regular treatments of water in such areas is recommended.
- We recommend changing the pathway of drains discharging or treating wastewater before discharging into water. This is strongly recommended.
- A public awareness program should be launched to promote knowledge and awareness of the provision of drinking water to humans around their areas of residence.
- To enhance water quality for aquatic life suitability, assessment study should be conducted every year to understand the water quality status. Further research is needed to document the effects of each agricultural drain or industrial factory on the Nile River.

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