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Water Quality Assessment for the Egyptian Northern Wetlands (Manzala and Burullus) Using WQI and MI Indices

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ABSTRACT

The northern coastal wetlands suffer from environmental pollution since they receive industrial, domestic, and agricultural drainage wastewater directly without treatments which has a negative impact on water as a substantial natural resource. Thus, this work aimed to assess the suitability of water quality in Manzala and Burullus wetlands for various uses through the determination of some physicochemical parameters. A total number of 32 representative surface water samples were collected and analyzed for pH, EC, salinity, TDS, turbidity, SO_4, Cl^-, HCO_3, Mg^+, Ca^{2+}, K^+, Na^+, and some heavy metals, such as Pb, Zn, Cu, Fe, and Cd. Two principal models namely water quality and metal indices (WQI, MI) were calculated to briefly estimate the water quality status. The results showed that the values of WQI in the Manzala Wetland ranged from 231.04 to 885.7, while it ranged from 191.8 to 589.8 in the Burullus Wetland. Moreover, the metal index values for irrigation purposes of all, except two stations, were less than 1, and all values for the aquatic life were more than 1. Therefore, nearly all the analyzed water samples from the Manzala and Burullus wetlands can be used for irrigation while categorized as unsuitable for the aquatic life. It is highly recommended that drainage water should be treated before discharging into the wetlands to comply with water quality standards. In addition, temporal assessment of water resources should be constantly conducted to mitigate the potential impacts and sustain water resources.

INTRODUCTION

The Egyptian Mediterranean coast, which is considered arid to hyper-arid, has five coastal wetlands, namely Mariut, Idku, El-Burullus, El-Manzala, and El-Bardawil. These wetlands constitute about 25% of the total Mediterranean wetlands. All of them are directly connected to the sea, except the Mariut Wetland. More than 20% of Egypt’s total population lives along the northern coastal zone of the country, with more than 40% of economic activities including industry, agriculture, tourism, petroleum and mining activities, and urban development concentrated along the coast. Unfortunately, many factors directly or indirectly threaten the Egyptian coastal wetlands’ ecological system. The degradation of these coastline habitats due to the rapid development and urbanization leads to an imbalance in the ecosystems and generates polluting elements that affect the quality of these frail and precious areas, mainly due to the discharge of large quantities of agricultural, industrial, and municipal wastes through several drains and factories **(Ghani & Shreadah, 2021)**.

Although the Egyptian northern wetlands are productive ecosystems that provide a good quantity of fish, they are usually under pressure from industrial activities and potentially polluting activities. Therefore, continuous monitoring is required to develop feasible approaches to mitigate fish contamination and the associated human health risks. The Egyptian government recently launched a program and established a strong policy framework to eliminate pollution and-reduce the release of harmful contaminants in these wetlands **(El Kafrawy *et al*., 2019; Shreadah *et al*., 2020)**.

The poor quality of the Egyptian northern wetlands water contaminatesthe Mediterranean Sea and menaces the health and livelihoods of millions of humans since they have been the main source of fish in Egypt for a long time. These wetlands are located on the Mediterranean coast of the Delta and cover about 6% of the non-desert surface area of Egypt. Moreover, they have always contributed more than 40% of the country's total fish production till 1991, then decreased to less than 12.22% **(El-Hamid *et al*., 2017)**.

The ecosystem of the Egyptian northern wetlands is controlled by natural and man-induced factors. As a result of the increasing population and after the construction of the Aswan High Dam, which provides inexpensive electric power, industrial and agricultural activities have increased rapidly in the delta region during the last decade. This economic development led to serious environmental hazards, especially in the Manzala and Brullus wetlands, which are converted into enormous basins in which industrial wastewater, agricultural drainage, and sewage effluents are poured directly without treatment, which affects water quality **(Shalaby *et al*., 2017)**.

Water quality is “a measure of the suitability of water for different uses according to physical, chemical, biological, and organoleptic (taste-related) properties, based on national or international standards. WQI is a mathematical framework through which large water quality data are converted into a single number and has common categorizations as excellent, good, poor, very poor, and unsuitable. It can provide simplistic information from complex water quality data to the public and managers **(Abdudayem & Scott, 2014)**.

Heavy metals (HMs) are considered the most significant pollutants in the aquatic environments due to their persistence, teratogenicity, mutagenicity, carcinogenicity, and ability to bioaccumulate in food chains **(Yang *et al*., 2017; Karimi *et al*., 2020; Zhao *et al*., 2020)**. Several known exposure pathways to HMs include ingestion via drinking water, feeding on aquatic organisms, dermal contact, and consuming agricultural products irrigated by contaminated water **(Mbuthia *et al*., 2014; Biswas *et al*., 2017; Yang *et al*., 2017; Njuguna *et al*., 2020)**. Additionally, HMs may be generated by natural sources or anthropogenic activities **(Mohammadi *et al*., 2020; Shams *et al*., 2020)** and pose serious threats to human health safety **(Setia *et al*., 2020; Renu *et al*., 2021)**.

This study aimed to determine physicochemical parameters to assess water quality based on WQI and identify the pollution state according to the metal index calculations in both Manzala and Burullus wetlands. In addition, it investigates the effect of the ongoing management and development of Manzala Wetland on the improvement of water quality.

MATERIALS AND METHODS

Study area

The study area represents two important wetlands in the Nile Delta of Egypt, namely, Manzala and Burullus, as shown in Figs. (1, 2). Manzala Wetland is located on the northeastern edge of the Nile Delta, separated from the Mediterranean Sea by a sandy beach ridge. It is the largest of the delta wetlands, and it is bordered by the Mediterranean Sea to the north and the north-east, the Suez Canal to the east, Dakahlia and Sharkia Provinces to the south, and the Damietta branch of the Nile to the west, as shown in Fig. (1). The wetland lies within three governorates and the two macroeconomic regions of the Suez Canal and the Delta. It is located between latitudes 31º 00′51″ - 31º 31′25″N and longitudes 31º 46′ 10″ - 32º 19′17″ E. It extends 64.5km in its maximum length, 49km in its maximum width, and 239km in total length of the shoreline. The wetland size has decreased; the rate of shrinking of the total area from 1922 to 1995 was 5.22km^2/ year. The greater loss areas were detected along the western and southern borders of the wetland. The area of the wetland was 1907km^2 in 1900, which reached about 909.85km^2 when measured by Landsat imagery in 1981. The area of the open water is only about 700km^2 due to the presence of a large number of islets in the wetland **(Sallam & Elsayed, 2018)**.

Burullus Wetland is among the five Egyptian lagoons, located totally inside the Nile Delta (Fig. 2). It is a shallow coastal lagoon with a water depth ranging from 0.5 to 2.0m. It was declared a national protectorate in 1998 and added to RAMSAR sites. The wetland was ranked as the second largest lagoon in Egypt, with an area of 42,000ha and extends in an elliptical elongated shape. It is placed between the two Nile River branches (Rosetta and Damietta) and connects to the Rosetta Branch by the Brimbal Canal at the west. It extends in alignment with the Mediterranean, where sand bars and dunes cover the land on its seaward side. A single narrow channel of 44m wide and 250m long connects the wetland with the Mediterranean from the north and is considered a chocked lagoon. This outlet represents the exclusive chance for water renewal by exchange with the adjacent sea. The water is in a continuous movement toward the sea as the lagoon surface is above the mean sea level by 25 to 60cm. Burullus Wetland is mainly a receiving reservoir for agricultural drainage waters from 546,000ha (1,300,000 feddans), which represents about 74.3% of the Nile Delta region **(Shalby *et al.*, 2020)**.

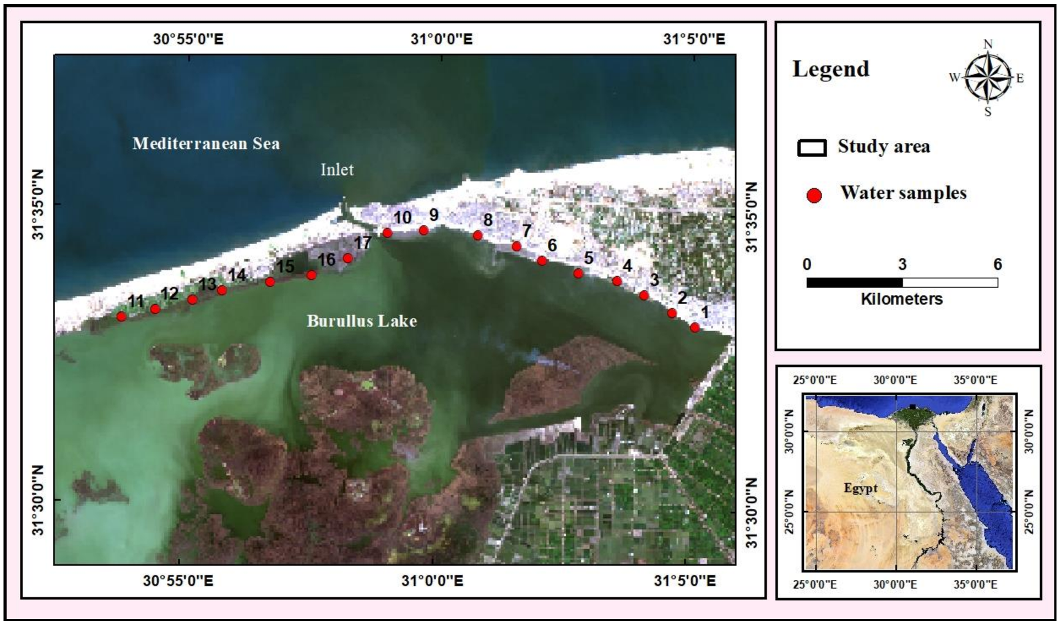

Fig. 1. Water sampling locations in Manzala Wetland

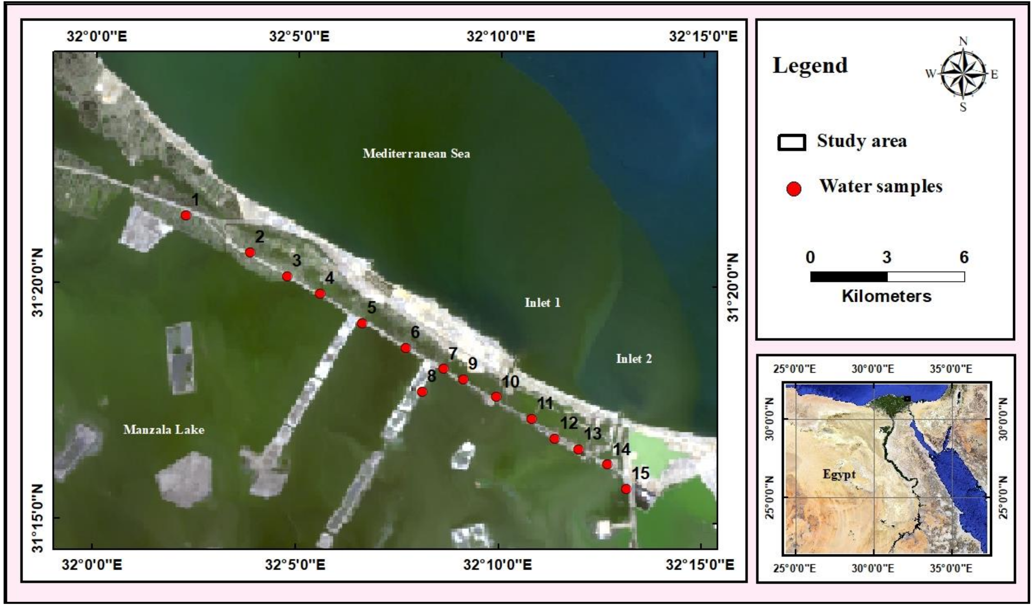

Fig. 2. Water sampling locations in Burullus Wetland

Sampling and analysis

The geographic location

The global positioning system (GPS) was used to determine longitudes and latitudes for each site in the study area, which is represented by two regions (Figs. 1, 2).

The first one includes the fifteen stations inside Manzala Wetland, while the second represents the seventeen stations located inside Burullus Wetland.

Water sampling

Thirty-two surface water samples were collected below the water surface by dipping bottles into the wetland for heavy metals and water quality parameters in August and September 2020 from the stations in the two regions. Water samples were collected in one-liter high-density polyethylene bottles, which were previously acid-treated, rinsed with de-ionized water, dried, and stored to prevent contamination. The samples were kept at a temperature of about 4°C and transferred to the laboratory using an icebox to prevent any change in water composition. Methods of preservation were limited to refrigeration, pH control, and chemical addition.

Water samples analysis

The physicochemical analyses of the collected water samples were carried out in the laboratories of the Chemistry and Environmental Science Departments at the Faculty of Science, Damietta University. The analyzed parameters included pH, electrical conductivity, salinity, turbidity, total dissolved solids, major cations and anions (sodium, potassium, calcium, magnesium, chloride, sulfate, and bicarbonate) in addition to some heavy metals, such as cadmium, copper, zinc, iron, and lead.

All the analyses of physicochemical parameters for the collected water samples were conducted according to the standard methods for the examination of water and wastewater **(APHA, 2017)**.

The salinity (‰) and electrical conductivity (EC; mS/cm) of the samples were measured using a salinity-conductivity meter (Digital Portable TDS/Conductivity meter Model 8033 HANNA, USA). The turbidity was measured by the Nephelometric method (Al 1000 Turbidimeter, Aqualytic, Germany measuring 0-200 NTU). Moreover, the total dissolved solids (g/ L) were measured by a TDS meter (Digital Portable TDS/Conductivity meter Model 8033 HANNA, USA). The pH of water samples was measured using a digital pH meter (model #5900-25, Chicago) according to the electrometric method after calibration with a standard buffer solution of pH 4, 7, and 10.

Sulfate and chloride were quantified by turbidimetric and Mohr (Argentometric) methods, respectively. The total alkalinity of carbonates and bicarbonates was determined a few hours after collection by titration against 0.02N H_2SO_4 or HCl using phenolphthalein and methyl orange as indicators.

The total calcium and magnesium hardness as $CaCO_3$ of the water samples were determined according to the EDTA titrimetric method. Sodium, potassium, and heavy metals were analyzed by the flame atomic absorption (PerkinElmer, Atomic Absorption

Spectrometer, PinAAcle 500). Water samples were determined for heavy metals by solvent extraction techniques and recovered by nitric acid aqueous solution.

Water quality index (WQI)

The WQI model is a common tool for the assessment of surface water quality, as it allows the conversion of extensive water quality data into a single value using aggregation techniques **(Uddin *et al.*, 2021)**. The pollution index is a valuable approach to give information about water quality and may be described as a rating that reflects the compound effect of different water quality factors on the whole water quality **(El-Feky *et al.*, 2019)**. Moreover, WQI is useful for the measurement of water quality alteration over time or comparing changes in water quality in a region. In the current study, WQI was calculated using equation 2, and rating q_i for the water quality factor was obtained using the following expression **(El-Hamid *et al.*, 2017)**:

$$qi = 100 \times [\frac{Vi}{Si}]$$

(1)

Where, S_i is the standard of the stream water quality and V_i is the observed data of the factor at a known sampling site according to all parameters. The equation emphasizes that q_i = 100 if the displayed data are impartial and equal to the standard one. Therefore, the larger values of q_i revealed polluted water. The quality rating qi related to each parameter can be delimited to compute the WQI using the following equation:

$$WQI = \sum qi$$

(2)

Where, i = 1. The average water quality index (AWQI) for n factors was computed using the following relation:

$$AWQI = \sum qi/n$$

(3)

Where, n is the number of parameters. AWQI was classified into 4 categories: good (0.0–100), medium (100- 150), bad (150– 200), and very bad (over 200), as displayed in Table (1).

Table 1. Categorization of water quality in accordance with WQI

WQI value	Water category
0-100	Good
100-150	Medium
150-200	Bad
Over 200	Very bad

Metal index (MI)

Metal index **(**MI**)** depends on a total trend assessment of the current status, as the higher the metal concentration compared to the respective maximum sllowable concentration (MAC), the worse the quality of the water. MI value >1 is a warning threshold **(El Sayed *et al*., 2023)**. According to **Tamasi and Cini (2004)**, the MI is calculated using the following formula:

$$MI = \sum_{i=1}^{n} Ci/(MAC)i \quad (4)$$

Where, Ci and MAC are the element concentration and maximum allowable concentration, respectively. The maximum allowable concentration for heavy metals is presented in Table (2).

Table 2. Maximum allowable concentration in mg/ l used for metal index

Parameter	Unit	$(MAC)_i$ (FAO, 1994) (for irrigation)	$(MAC)_i$ (CCME, 2007) (for aquatic life)
Pb	mg/L	5	0.007
Zn		2	0.05
Cu		0.2	0.004
Fe		5	0.3
Cd		0.01	0.001

Statistical analysis

Univariate analysis

One-way ANOVA, with Tukey's-b test, was employed to test the spatial variability of environmental factors. Pearson correlation analyses were performed to define the relationships between some selected parameters. ANOVA and correlation analyses were performed using SPSS v.26.

Multivariate analysis

The spatial environmental status of the thirty-two sampling stations was summarized using principal component analysis (PCA) ordination. The PCA was performed from the linear correlation matrix of the environmental variables after the data were subjected to logarithmic transformation **(Alzeny *et al*., 2021)**. The software package CANOCO, version 4.5, was used for the PCA analysis.

Correlation analysis

In a complex lacustrine system, variations of any environmental factors are not independent. However, it is interdependent with other environmental parameters, which can be analyzed using correlation method. Correlation analysis can estimate the strength and direction of linear relationships between pairs of continuous variables.

RESULTS AND DISCUSSION

Physicochemical characteristics

The results of physicochemical parameters in the study areas are summarized in Table (3). The pH approximately affects all biochemical processes in water, such as enzyme activity, solubilizes, uptakes certain ions as ammonia. It limits the distribution of biodiversity in aquatic habitats. Various species can thrive within different pH ranges with the optimum values (between 6.5 and 8.5) for most aquatic organisms **(WHO, 2004)**. The pH values can also affect the biological activities of microbial metabolites, which influence the further usage of succeeding metabolic products **(Alprol *et al*., 2021)**. The pH values ranged from 7.62 (at station 9) to 8.94 (at station 2) with an average value of 8.31 in Manzala Wetland, while it ranged between 7.97 (at station 1, east of the drain) and 9.03 (at station 14) with an average value of 8.56 in Burullus Wetland. The obtained results are consistent with those reported by **El-Alfy (2015)** and **El-Hamid *et al.* (2017)**, who recorded 8.5, 8.7 as average pH values in the aquatic samples of Manzala Wetland. **Goher *et al*. (2017)** and **Al-Agroudy and Elmorsi (2022)** stated an average pH value of 7.19 and 7, respectively. The obtained results also match those reported by **El-Hamid *et al*. (2017)**, **Alprol *et al*. (2021)** and **Al-Afify *et al*. (2023)**, who recorded 8.5, 8.09 and 8.35 as averages pH values in Burullus Wetland, indicating that the pH values are on the alkaline side (pH> 7.0). The alkalinity of surface water samples indicates increasing photosynthetic assimilation of dissolved inorganic carbon by plankton **(Mosaad *et al*., 2022)**.

Table 3. Statistical summary of the physicochemical parameters for the water samples of Manzala and Burullus wetlands

Parameter	Unit	Manzala				Burullus			
		Mean	Min	Max	Std. Dev.	Mean	Min	Max	Std. Dev.
pH		8.31	7.62	8.94	0.4	8.56	7.97	9.03	0.28
TDS	g/L	16.07	2.96	26.4	7.05	4.36	2.14	7.95	1.97
Salinity	‰	16.69	3	27.4	7.34	4.49	2.2	8.2	2.05
EC	ms/cm	23.21	5.1	35.9	8.9	7.69	4.1	13.63	3.11
Turbidity	NTU	23.11	13.7	33.91	6.90	76.57	13.2	213	54.45
Chloride	mg/L	9916.93	1399.57	17994.54	4662.6	2258.12	899.72	4498.61	1171.74
Sulfate		26.61	3.88	87.14	22.23	15.41	2.25	25.29	6.80
Bicarbonate		301	270	335	17.03	42.65	20	55	10.17
Calcium		227.98	63.33	443.28	134.97	82.32	44.33	101.32	14.85
Magnesium		733.67	246.79	1122.08	248.65	195.67	91.45	310.53	81.64
Sodium		633.40	106.56	898.4	223.87	219.85	100.28	346.2	82.28
Potassium		28.3309	8.35	48.14	10.26	47.04	23.97	80.29	17.12
Lead		0.045	0.01	0.11	0.024	0.038	0.01	0.08	0.018
Zinc		0.12	0.1	0.15	0.016	0.1096	0.05	0.17	0.033
Copper		0.012	0	0.03	0.009	0.0097	0	0.0299	0.009
Iron		0.076	0.008	0.15	0.05	0.1898	0.0099	0.77	0.19
Cadmium		0.0049	0.0016	0.01	0.0024	0.0032	0.0019	0.006	0.00097

Total dissolved solids (TDS) are a measure of the combined content of all inorganic and organic matter or salts found in water. The main constituents are usually the cations (sodium, potassium, calcium, and magnesium) and the anions such as carbonate, bicarbonate, nitrate, chloride, sulfate, etc. Among the components of TDS is hardness, which consists of dissolved calcium and magnesium in the water. Some of the above-mentioned ions are essential, whereas others are toxic to human health **(Islam *et al*., 2016)**. The TDS values ranged from 2.96g/ L (at station 14, inlet 2) to 26.4g/ L (at station 1), with an average value of 16.07g/ l in Manzala Wetland. The resulting data are less than those reported (1.033 to 43.406g/ L) by **Ismail and Hettiarachchi (2017)**. However, they are more than those obtained (4.47, 2 and 1.46g/ L, respectively) by **El-**

Badry (2016), **Elmorsi *et al.* (2017)** and **Al-Agroudy and Elmorsi (2022)**. In Burullus Wetland, TDS values fluctuated between 2.14g/ L (at station 3) and 7.95g/ L (at station 9), with 4.36g/ L as an average value. The average value is in the range of the results of **Melegy *et al.* (2019)**, who recorded a range of 1.5 to 10.2g/ L and **Al-Afify *et al.* (2023)**, who reported an average of 5.70g/ L for TDS of the collected water samples from Burullus Wetland.

Salinity has a considerable impact on measuring multiple conditions of the natural water chemistry and aquatic biological processes **(Magouz *et al.*, 2021)**. Water salinity is categorized into fresh (< 0.5g/ L), brackish (0.5– 30g/ L), saline (30– 50g/ L), and brine (> 50g/ L) water. In addition, it is one of the most significant factors that affect the composition, distribution, dynamics, and diversity of populations in many aquatic environments **(El-Enany, 2004)**. The salinity values in Manzala Wetland varied from 3‰ (at station 14, inlet 2) to 27.4‰ (at station 1), with a mean value of 16.69‰. The obtained data are similar to those recorded (15.6‰) by **El-Hamid *et al.* (2017)**, while **Elmorsi *et al.* (2017)** and **Goher *et al.* (2017)** reported that the salinity average was 6.66 and 5.49‰, respectively. In Burullus Wetland, the salinity values ranged from 2.2‰ (at station 3) to 8.2‰ (at station 9), with an average value of 4.49‰. These results agree with those defined by **Alprol *et al.* (2021)**, who recorded 4.60 ‰ as a mean of salinity. On the other hand, **El-Hamid *et al.* (2017)** reported an average value of 10.8‰ and **El-Naggar and Rifaat (2022)** recorded 2.4‰ as a mean value of salinity. Water salinity showed the lowest value at Burullus Wetland (2.2‰), and the highest value was recorded at Manzala Wetland (27.4‰), and this may be due to seawater intrusion along the inlet area **(El-Hamid *et al.*, 2017)**.

Electrical conductivity is the ability of water to carry an electric current due to the movement of ions and is an excellent indicator of TDS and salinity, which affect the taste of potable water. It is a water-quality *in-situ* parameter, measured by reliable and rapid modern instruments **(McCleskey *et al.*, 2011)**. The values of EC ranged from 5.1ms/ cm at station 14 (inlet 2) to 35.9ms/ cm at station 1, with an average value of 23.21ms/ cm in Manzala Wetland. **Goher *et al.* (2017)** and **El-Shazly (2019)** reported 9.2 and 17.8mS/ cm as the mean values of EC, respectively. These variations may be attributed to the increase in the evaporation rate, where the temperature influences the rate of rock weathering and precipitation processes **(Mohamed, 2005)**. In Burullus Wetland, EC values varied from 4.1ms/ cm at station 3 to 13.63ms/ cm at station 10, with an average value of 7.69ms/ cm, which nearly matches with that obtained (9.44mS/ cm) by **Al-Afify *et al.* (2023)**. However, these values disagree with those reported (27.5mS/ cm) by **El-Amir *et al.* (2016)**. Moreover, these values are less than that recorded (2.14 to 54.8mS/ cm) by **Ali (2011)** and **EL-Zeiny and EL-Kafrawy (2016)** in the aquatic samples of Burullus Wetland.

Turbidity is a visional limitation of water clearness which is decreased by the presence of unsellable solids and dissolved colored substances. Generally, water turbidity is considered a measurement indicator of water purity in terms of clarity and total suspended solids and has a great impact on the water's appearance **(Moyel & Hussain, 2015)**. In Manzala Wetland, turbidity values fluctuated between 13.7NTU at station 8 and 33.91NTU at station 11, with an average value of 23.11NTU, which is more than that recorded (10NTU) by **Deyab *et al.* (2019)** and less than that recorded (39.05NTU) by **Soliman *et al.* (2022)**. Turbidity values ranged from 13.2NTU at station 1 to 213NTU at station 4, with an average value of 76.57NTU in Burullus Wetland; this value is higher than that recorded (9.6NTU) by **Mohsen *et al.* (2023)**. This may be attributed to the provisional resuspension of organic pollutants and sediments in water by fisheries or development activities **(Haroon *et al.*, 2018)**.

The Cl^- contents of Manzala Wetland water varied from 1399.57mg/ L (at station 14, inlet 2) to 17994.54mg/ L (at station 1), with an average value of 9916.93mg/ L. **EL-Shafei (2016)** reported that Cl^- ranges of collected water samples from Manzala Wetland are 470- 11,500mg/ L, and **Elmorsi *et al.* (2017)** recorded 400- 13000mg/ L as Cl^- ranges in aquatic samples of Manzala Wetland. **Soliman *et al.* (2022)** stated that the average value of Cl^- was 1674.4mg/ L. While the concentration of Cl^- in Burullus Wetland water fluctuated between 899.72mg /L (at station 3) and 4498.61mg/ L (at station 9) with an average of 2258.12mg/ L. The obtained results disagree with those documented by **El-Amier *et al.* (2016)**, who recorded 9930.3mg/ L as the average value of Cl^- in the aquatic samples of Burullus Wetland**,** and are similar to those ascertained by **Al-Afify *et al.* (2023)**, who recorded 3480mg/ l as an average Cl^- value. The dominant anion (Cl^-) and major cations (Na, K, Ca, and Mg) were primarily controlled by the infiltration of drainage water through various drains, the influx of seawater, and finally, the received freshwater from the Nile via the Brimbal Canal **(Al-Afify *et al.*, 2023)**.

The SO_4^{2-} contents of the collected water samples from Manzala Wetland ranged between 3.88mg/ L at station 6 and 87.14mg/ L at station 2, with an average value of 26.61mg/ L; this average is less than that obtained (484.18mg/ L) by **Mashaly *et al.* (2020)**. In Burullus Wetland, the SO_4^{2-} concentration of water samples varied from 2.55mg/ L (at station 13) to 25.29mg/ L (at station 6), with an average value of 15.41mg/ L, which is less than that recorded (86.3, 138.01mg/ L) by **El-Amier *et al.* (2016)** and **Al-Afify *et al.* (2023)**.

The HCO_3^- contents of Manzala Wetland water samples ranged from 270mg/ L (at station 13) to 335mg/ L (at station 9) with a mean value of 301mg/ L, which is consistent with those obtained (216- 352.56mg /L) by **EL-Shafei (2016)** and (192.05mg /L**)** **Mashaly *et al.* (2020)** in the aquatic samples of Manzala Wetland. **Elmorsi *et al.* (2017)** documented a mean value of HCO_3^- as 201mg/ L; **El-Hamid *et al.* (2017)** recorded 473.2mg/ L as a mean value of HCO_3^-. In Burullus Wetland, the contents of HCO_3^- in the collected water samples varied from 20mg/ L (at station 9) to 55mg/ L (at stations 1, 4, and 11), with an average value of 42.65mg/ L, which is less than that reported (253, 524, and 313.38mg /L) by **El-Amier *et al*. (2016)**, **El-Hamid *et al*. (2017)**, and **Al-Afify *et al*. (2023)**, respectively. These fluctuations may be due to the spatial and temporal variations during sample collection.

The values of Ca^2 in the water samples of Manzala Wetland fluctuated between 63.33mg/ L (at station 14, inlet 2) and 443.28mg/ L (at station 1), with a mean value of 227.98mg/ L, which is less than the 252mg/ L recorded by **El-Hamid *et al*. (2017)** and consistent with the 223mg/ L obtained by **Soliman *et al*. (2022)** in the aquatic samples of Manzala Wetland. In Burullus Wetland, the Ca^{2+} contents of water varied from 44.33mg/ L (at station 8) to 101.32mg/ L (at stations 1, 9, 10, and 11), with an average value of 82.32mg/ L, which is nearly more than that documented (60.66 and 76.81 mg/L) by **El-Amier *et al*. (2016)** and **Al-Afify *et al*. (2023)**, respectively. Moreover, it is less than that reported (111mg /L) by **El-Hamid *et al*. (2017)**.

The Mg^{2+} contents of the studied water samples from Manzala Wetland were in the range of 246.79mg/ L (at station 14, inlet 2) and 1122.08mg /L (at station 2), with an average value of 733.67mg/ L, which is nearly similar to that obtained (665.5 mg/L) by **EL-Shafei (2016)** and more than that recorded (104.57mg/ L) by **Soliman *et al*. (2022)** in the aquatic samples of Manzala Wetland. In Burullus Wetland, the concentrations of Mg^{2+} in the collected water samples varied from 91.45mg/ L (at station 3) to 310.53mg /L (at station 9) with a mean value of 195.67mg /L; this result is less than that obtained (239.77 and 258.39mg /L) by **El-Amier *et al*. (2016)** and **Al-Afify *et al.* (2023)**.

In Manzala Wetland, the values of Na^+ in the collected water samples fluctuated between 106.56mg/ L (at station 14, inlet 2) and 898.4mg /L (at station 2), with an average value of 633.40mg/ L, which is consistent with that recorded (622.5mg/ L) by **Soliman *et al*. (2022)**, and is slightly more than that obtained (519.76mg/ L) by **Mashaly *et al*. (2020)**. This may be due to the prevailed spatial and temporal conditions during the sample collection. In Burullus Wetland, the Na^+ contents of water samples ranged from 100.28mg/ L (at station 3) to 346.2mg/ L (at station 15), with an average value of 219.85mg/ L, which is less than that documented (1874.6 and 1323mg/ l) by **El-Amier *et al*. (2016)** and **Al-Afify *et al*. (2023)**, respectively. The high concentrations of Na^+, Ca^{2+}, and Mg^{2+} in water may be ascribed to clay minerals, such as illite, albite, fluorite, halite, limestone, dolomites, gypsum, sylvite, the weathering of soda Feldspar (Albite), potash feldspars (Orthoclase and Microcline), and anthropogenic activities **(Mosaad *et al*., 2022)**.

The K^+ contents of the addressed water samples from Manzala Wetland were in the range of 8.35mg /L (at station 13) and 48.14mg/ L (at station 2), with an average value of 28.3309mg/ L, which coincides with the value reported (27.4mg /L) by **Soliman *et al*. (2022)**. Moreover, the current value is less than that recorded (57.06- 76.34mg/ L) by **Al-Agroudy and Elmorsi (2022)**. In Burullus Wetland, the concentration of K^+ in the studied water samples varied from 23.97mg/ L at station 8 to 80.29mg/ L at station 10, with an average value of 47.04mg/ L, which is significantly less than that obtained (72.56 and 80.11mg/ L) by **El-Amier *et al*. (2016)** and **Al-Afify *et al.* (2023)**, respectively. Comparison between mean concentrations of physicochemical parameters of Manzala and Burullus wetlands water is displayed in Tables (4, 5).

Table 4. Comparison between mean concentrations of physicochemical parameters of Manzala Wetland water in the present study with the previous studies and with the permissible limits for irrigation

Reference	pH	TDS (g/l)	Salinity (‰)	EC (ms/cm)	Turbidity (NTU)	Cl^- (mg/l)	So_4^{2-} (mg/l)	HCO_3 (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)
El-Alfy (2015)	8.5											
El-Shafei (2016)										665.5		
El Badry (2016)		4.47										
Elmorsi *et al*. (2017)	8.22	2	6.66			866		201				
Goher *et al*. (2017)	7.91		5.49	9.2								
El-Hamid *et al*. (2017)	8.7		15.6					473.2	252			
El-Shazly (2019)				17.8								
Deyab *et al*., (2019)					10							
Mashaly *et al*. (2020)							484.18	192.05			519.76	
Al-Agroudy and Elmorsi (2022)	7	1.46										
Soliman *et al*. (2022)					39.05	1674.4			223	104.57	622.5	27.4
FAO (1994)	8.5	2	-	3	-	1063	960	610	400	60	919	2
The Present Study	8.31	16.07	16.69	23.21	23.11	9916.93	26.61	301	227.98	733.67	633.40	28.3

Table 5. The comparison between annual mean concentrations of physicochemical parameters of Burullus Wetland water in the present study with the previous studies and permissible limits for irrigation

Reference	**pH**	**TDS (g/l)**	**Salinity (‰)**	**EC (ms/cm)**	**Turbidity (NTU)**	**Cl^- (mg/l)**	**So_4^{2-} (mg/l)**	**HCO_3 (mg/l)**	**Ca^{2+} (mg/l)**	**Mg^{2+} (mg/l)**	**Na^+ (mg/l)**	**K^+ (mg/l)**
El-Amier *et al*. (2016)	8.71			27.5		9930.3	86.3	253	60.66	239.77	1874.6	72.56
El-Hamid *et al*. (2017)	8.5		10.8					524	111			
Alprol *et al*. (2021)	8.09		4.60									
El-Naggar and Rifaat (2022)			2.4									
Mohsen *et al*. (2023)					9.6							
Al-Afify *et al*. (2023)	8.53	5.70		9.44		3480	138.01	313.38	76.81	258.39	1323	80.11
FAO (1994)	8.5	2	-	3	-	1063	960	610	400	60	919	2
The present Study	8.56	4.36	4.49	7.69	76.57	2258.12	15.41	42.65	82.32	195.67	219.85	47.04

Heavy metals

Heavy metals exist throughout the earth's crust as naturally occurring elements. Anthropogenic activities such as industrial production, mining and smelting operations, domestic and agricultural use of metals, and metal-containing compounds result in most environmental contamination and human exposure **(Mosaad *et al*., 2022)**.

Research on heavy metals in rivers, wetlands, fish, and sediments has received prime attention in the last decades due to their persistence and tendency for bioaccumulation by aquatic organisms. The hurtful effects of some trace elements on living organisms were well-authenticated in the Egyptian ecosystems **(Ghani & Shreadah, 2021)**. The average values and ranges of heavy metal concentrations in the study areas are displayed in Table (3).

Lead is a highly toxic metal present in all environmental components; thereby Pb^{2+} is considered a very significant ion in aquatic systems **(Al Prol *et al*., 2019)**. Pb^{2+} is considered one of the major environmental toxins in industrial areas of the world, and animals are frequently exposed to it. Numerous environmental factors, including industrial pollution, agricultural practices, cosmetics, automobiles, paints, and contaminated feed and soil, can cause Pb poisoning, which is especially common in animals. Accumulated Pb^{2+} is toxic in its chemical composition, whether it is ingested or consumed in feed or water **(Tahir *et al*., 2023)**. In Manzala Wetland, lead values ranged from 0.01mg/ L at station 15 to 0.11mg/ L (at station 14, inlet 2), with an average value of 0.045mg/ L. **Zahran *et al*. (2015)** reported that lead concentrations in the aquatic samples of Manzala Wetland ranged from 0.0016 to 0.008mg/ L. The higher value may be attributed to the dissolution and release of lead from the wetland bottom sediment due to the changes in spatial and temporal conditions during the sampling process, as well as an increase in the concentration of pesticides, fertilizers, and agrochemicals by agricultural run-off, while the lower value may be due to the uptake and accumulation of Pb^{2+} by aquatic organisms in the surface water **(Goher *et al*., 2017)**. The concentration of lead in water is affected by organic matter, pH, hardness, and the presence of other metals. Moreover, Pb^{2+} concentration depends on the form by which it is present in the aqueous systems, as $PbSO_4$ is much more soluble than carbonate form, while PbS has very low solubility. In Burullus Wetland, lead values ranged from 0.01mg/ L at station 15 to 0.08mg/ L at station 10, inlet 1, which are more than the range values documented (0.0003 to 0.019mg/ L) by **Alprol *et al*. (2021)**. This may be attributed to the release of Pb from sediment by several environmental factors, temporal improvement activities, or the exchange of Pb^{2+} forms due to spatial and temporal variation in the aquatic conditions. In addition, the high level of lead may be a result of industrial and agricultural effluents and the fishing boats painted with a dye containing a high Pb^{2+} content and publicized along the study area coast. In addition, the highest values of lead can disturb the phytoplankton health system, which is a crucial source of oxygen generation in aquatic systems and causes congestion of the gastrointestinal tract, hemorrhages, and fish kidneys **(Alprol *et al*., 2021)**.

The concentrations of zinc (Zn^{2+}) in water samples collected from Manzala Wetland were in the range of 0.1 to 0.15mg/ L at stations 12 and 4, respectively, with an average value of 0.12mg/ L, which are less than those obtained **(**0 to 0.35mg/ L) by **Ismail and Hettiarachchi (2017)** in the aquatic samples of Manzala Wetland. The present results showed that the lower values of zinc may be due to adsorption on precipitated Fe $(OH)^3$ or uptake by aquatic organisms, while the higher values may be attributed to the discharges of domestic and agricultural effluents into the wetland **(Goher *et al*., 2017)**. In Burullus Wetland, zinc values ranged from 0.05mg/ L at station 10, inlet 1 to 0.17mg/ L at station 17, with an average value of 0.1096mg/ L, which are more than those recorded (0.0001 to 0.035mg/ L) by **Alprol *et al*. (2021)**. The relatively high Zn^{2+} level is suggestive of the industrial effluents, urbanization, and influence of refuse dumps and domestic sewage sources. It was documented that high temperatures and low dissolved oxygen in aquatic environments may lead to an increase in Zn^{2+} toxicity **(Abualnaja *et al*., 2021)**.

The concentration of copper (cu^{2+}) in the collected water samples from Manzala Wetland varied from 0mg/ L at stations 6, 15 to 0.03mg/ L at station 14, inlet 2, with a mean value of 0.012mg/ L which are less than the values reported (0.01 to 0.91mg/ L) by **Ismail and Hettiarachchi (2017)**. The higher values may be due to domestic sewage effluents and agricultural runoff, where domestic sources are the main copper contributors to the environment **(Goher *et al*., 2017)**. In Burullus Wetland, copper (Cu) values are undetected at stations 1, 6, 7, 8, and 15 and reached 0.0299mg/ L at station 3 with an average value of 0.0097mg/ L. The obtained values are less than those recorded (0.002 to 0.035mg/ L) by **Alprol *et al*. (2021)**. It was documented that the higher concentration of Cu^{2+} in aquatic environments may negatively impact the degradation of hydrocarbons by microorganisms due to the excessive breakdown of enzyme action **(Prol *et al*., 2017)**.

The contents of iron (Fe^{2+}) in the studied water samples collected from Manzala Wetland ranged from 0.008mg/ L at station 10, inlet 1 to 0.15mg/ L at station 4 with an average value of 0.076mg/ L which are less than those (0.01 to 0.63mg/ L) of **Ismail and Hettiarachchi (2017)**. The present results showed that the higher values may be attributed to the intrusion of seawater loaded with high concentrations of iron, while the lower values may be due to the high concentrations of dissolved oxygen that oxidize Fe^{2+} to Fe^{3+}, which may be adsorbed on an organic matter **(Goher *et al*., 2017)**. In Burullus Wetland, Fe values fluctuated between 0.0099mg/ L at station 17 and 0.77mg/ L at station 6, with a mean value of 0.1898mg/ L. These results concur with those recorded (0.007 to 0.22mg/ L) by **Alprol *et al*. (2021)** in the aquatic samples of Burullus Wetland. The high concentration of dissolved oxygen oxidizes Fe^{2+} to Fe^{3+}, which is subsequently hydrolyzed to form insoluble $Fe(OH)_3$ leading to a decrease in iron concentration in surface water. The maximum concentration of Fe^{2+} observed in the present study may be due to the discharge of industrial wastewater into the Mediterranean Sea coastal area. Moreover, **Eid *et al*. (2012)** found that Fe^{2+} concentrations in Burullus Wetland were high during the growing season. It was mentioned that high levels of Fe^{2+} may inhibit the microbial degradation of hydrocarbons since excessive values can inhibit enzyme function **(Alprol *et al*., 2021)**.

Cd^{2+} is among the greatest poisonous metals with prevalent carcinogenic effects in humans and is considered to be toxic with concentrations exceeding 0.01mg/ L in both irrigation and drinking water **(Ghoneim *et al.*, 2014; Ashour *et al.*, 2018)**. Cadmium (Cd^{2+}) values ranged from 0.0016mg/ L at station 10 (inlet 1) to 0.01mg/ L at station 13 in Manzala Wetland, with an average value of 0.0049mg/ L. The obtained results are less than those reported (0.0002 to 0.009mg/ L) by **Zahran *et al.* (2015)**. In Burullus Wetland, cadmium (Cd^{2+}) values ranged from 0.0019mg/ L at station 13 to 0.006mg/ L at station 8, with an average value of 0.0032mg/ L. The values of Cd^{2+} obtained by the current study are approximately similar to those recorded (0.00004 to 0.003mg/ L) by **Alprol *et al.* (2021)** in the aquatic samples of Burullus Wetland. The high value of Cd may be attributed to the discharge effluents from agricultural, domestic, and industrial drains **(Goher *et al.*, 2017)** in addition to boat activities that include the disposal of liquid wastes such as fishing boat exhaust as well as the materials used in the boat's coating paints **(Farouk *et al.*, 2020)**. Comparison between the annual mean concentrations (mg/L) of heavy metals in Manzala and Burullus wetlands water is presented in Tables (6, 7).

Table 6. Comparison between the annual mean concentrations (mg/l) of heavy metals of Manzala Wetland water in the present study with the previous studies and permissible limits for irrigation and aquatic life

Reference	Lead	Zinc	Cupper	Iron	Cadmium
Saeed and Shaker (2008)	0.099	0.464	0.513	1.416	0.044
Zahran *et al*. (2015)	0.0047	0.0052	0.0017	0.0296	0.0016
El-Badry (2016)	0.0058	0.0009	0.0028	-	0.0004
Ismail and Hettiarachchi (2017)	-	0.21	0.21	0.475	-
Gawad (2018)	0.0406	0.0332	0.0128	0.427	0.0034
El-Morsi *et al*.(2019)		0.099	0.042	0.306	
Morsy *et al*. (2020)	0.0311	-	0.02307	0.1065	0.00092
Mandour (2021)	0.00568	0.00878	0.00326	0.0381	0.00183
Al-Agroudy and Elmorsi (2022)	0.695	0.11	0.445	0.435	0.01
ESC (1994)	0.05	5	-	1	0.01
FAO (1994)	5	2	0.2	5	0.01
CCME (2007)	0.007	0.5	0.004	0.3	0.001
The present study	0.045	0.12	0.012	0.076	0.0049

Table 7. The comparison between the annual mean of heavy metals concentrations (mg/l) of Burullus Wetland water in the present study with the previous studies and permissible limits for irrigation and aquatic life

References	Lead	Zinc	Cupper	Iron	Cadmium
Saeed and Shaker (2008)	0.065	0.050	0.035	0.425	0.005
EL-shaer and ALabssawy (2019)	0.0511	0.01243	0.0261	0.62643	0.00207
Melegy *et al*. (2019)	0.046	0.108	0.068	0.148	0.002
Farouk *et al*. (2020)	0.05615	0.12823	-	0.2496	0.003983
Morsy *et al*. (2020)	0.04074	-	0.0249	0.1597	0.0018
Alprol *et al*. (2021)	0.0049	0.0113	0.0088	0.049	0.0012
ESC (1994)	0.05	5	-	1	0.01
FAO (1994)	5	2	0.2	5	0.01
CCME (2007)	0.007	0.5	0.004	0.3	0.001
The present study	0.038	0.1096	0.0097	0.1898	0.0032

Evaluation of water quality using WQI

In Manzala Wetland, WQI values ranged from 231.04 at station 14, inlet 2 to 885.7 at station 10, inlet 1. Overall, all stations were classified as "very bad water" (Fig. 3), and unsuitable for irrigation. In Burullus Wetland, WQI ranged from 191.8 at station 6 to 589.8 at station 10, inlet 1. All stations were classified as "very bad water", except for stations 6 and 8 that were classified as "bad water" (Fig. 4). Consequently, these waters were also unsuitable for irrigation, which reflects the influence of discharging wastewater into these important water resources without treatment. AWQI values along Manzala and Burullus wetlands were 542.5 and 351.9, respectively. WQI and AWQI are presented in Table (8). This confirms that the water quality of both Manzala and Burullus wetlands is categorized as "very bad water." These results are consistent with the results of **El-Hamid *et al*. (2017)** and **Zaghloul *et al*. (2023)**. Moreover, the results are more than those calculated (80.67, 68.23, and 90.24) by **Alprol *et al*. (2021)** along the northern Delta wetland Burullus during the years 2017, 2018, and 2019, respectively, which means that the waters are classified as good water quality (suitable for all uses) during the sampling period at most sites.

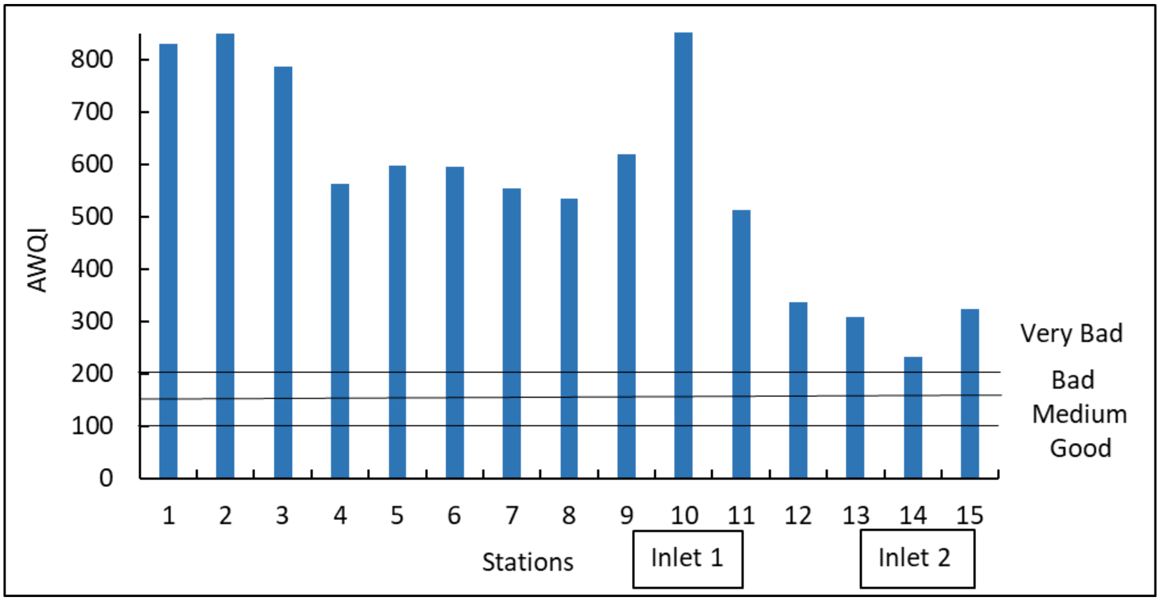

Fig. 3. Distribution of average water quality index (AWQI) in Manzala Wetland

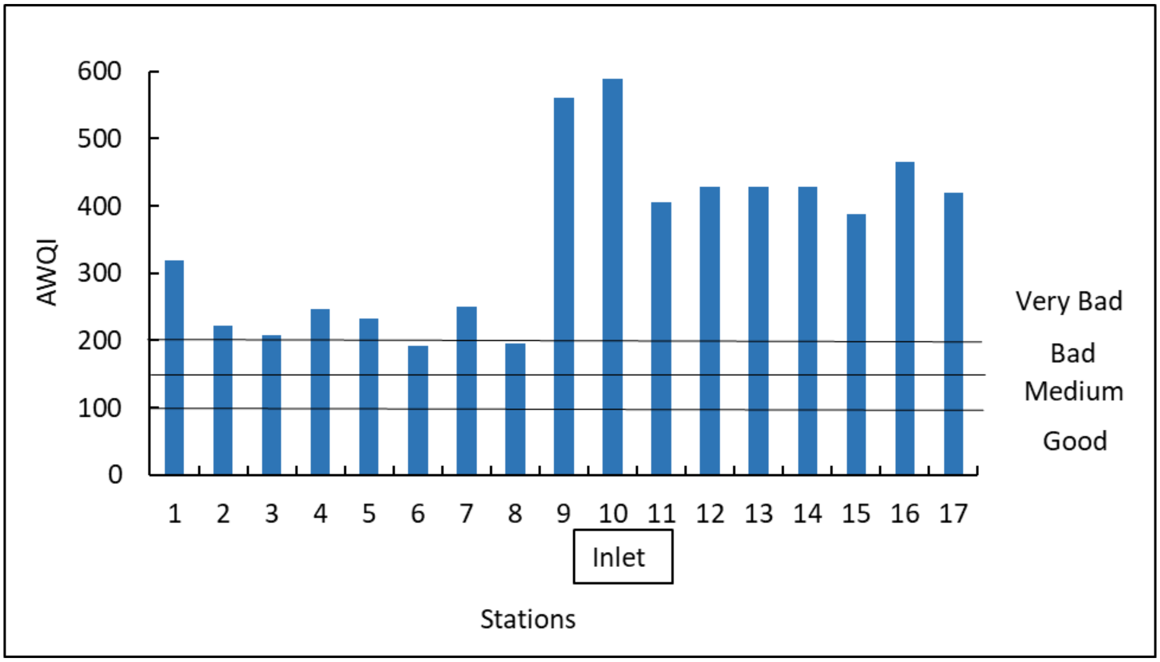

Fig. 4. Distribution of average water quality index (AWQI) in Burullus Wetland

Assessment of the water pollution using MI

It was found that metal index values for all stations, except stations 11 and 13, in Manzala Wetland, are less than 1, indicating the suitability of water for irrigation, while metal index values more than 1 indicate that water is inappropriate for the aquatic life, and this may be due to the enormous quantities of human, animal, and industrial wastes dumped into Manzala Wetland. In Burullus Wetland, metal index values for all stations are less than 1, which indicates unpolluted water for irrigation, while metal index values more than 1 indicates polluted water for aquatic life. The obtained results are similar to the results of **Zaghloul *et al*. (2023)**. **Goher *et al*. (2017)** ascertained that all the selected stations along both wetlands are seriously threatened with metal pollution for aquatic life usage (MI≥ 1). The metal index of Manzala and Burullus wetlands water is presented in Table (9).

Table 9. Metal index of the addressed metals in Manzala and Burullus Wetlands water according to guideline levels of irrigation and aquatic life

Site	Manzala				Burullus			
	MI value (Irrigation)	Rank	MI Value (Aquatic life)	Rank	MI value (Irrigation)	Rank	MI value (Aquatic life)	Rank
1	0.562	Unpolluted	15.852	Polluted	0.4155	Unpolluted	7.4637	Polluted
2	0.11	Unpolluted	18.819	Polluted	0.3429	Unpolluted	9.935	Polluted
3	0.5415	Unpolluted	15.861	Polluted	0.555	Unpolluted	19.8707	Polluted
4	0.6776	Unpolluted	21.413	Polluted	0.566	Unpolluted	17.1167	Polluted
5	0.5481	Unpolluted	14.7073	Polluted	0.5523	Unpolluted	15.484	Polluted
6	0.5969	Unpolluted	12.7712	Polluted	0.6169	Unpolluted	11.136	Polluted
7	0.523	Unpolluted	9.3586	Polluted	0.3894	Unpolluted	11.304	Polluted
8	0.395	Unpolluted	11.9143	Polluted	0.6467	Unpolluted	15.813	Polluted
9	0.885	Unpolluted	23.6781	Polluted	0.5605	Unpolluted	15.888	Polluted
10	0.213	Unpolluted	5.4586	Polluted	0.3423	Unpolluted	18.204	Polluted
11	1.015	polluted	23.1315	Polluted	0.4002	Unpolluted	13.932	Polluted
12	0.411	Unpolluted	16.005	Polluted	0.446	Unpolluted	16.718	Polluted
13	1.23	polluted	22.44	Polluted	0.3324	Unpolluted	12.2897	Polluted
14	0.9496	Unpolluted	32.8141	Polluted	0.5701	Unpolluted	16.56	Polluted
15	0.3895	Unpolluted	7.264	Polluted	0.29	Unpolluted	5.699	Polluted
16					0.451	Unpolluted	14.028	Polluted
17					0.456	Unpolluted	12.948	Polluted
Mean	0.6		16.766		0.47		13.788	

Statistical analysis

Pearson Correlation Matrix

The correlation matrix indicates the relationship among morphometric parameters **(Aly *et al.*, 2022)**. Correlation analysis was carried out using Pearson's correlation coefficient. The correlation matrix was calculated for the water quality parameters and is displayed in Table (10). The results of the correlation coefficient (r) were evaluated as follows: 0.0 means no correlation or independent parameters; 0.3- 0.5 (low); 0.5- 0.7 (medium); 0.7- 0.9 (high); and from 0.9 to 1 is very high correlation. In the present study, there were very high significant correlations between many parameters, such as TDS with salinity, EC, Cl, Ca, and Mg (r = 1.0, 0.994, 0.955, 0.954, 0.949, respectively). pH was highly negatively correlated with turbidity, Pb, Cu, and Cd (r = -0.1, -0.2, -0.3, and -0.283, respectively).

Table 10. Correlation matrix between parameters in water samples of the examined wetlands

Parameters	pH	TDS	Salinity	EC	Turbidity	Cl^-	So_4^{2-}	HCO_3	Ca^{2+}	Mg^{2+}	Na^+	K^+	Pb	Zn	Cu	Fe	Cd
pH	1																
TDS	0.083	1															
Sal.	0.085	1.000	1														
EC	0.049	0.994	0.994	1													
Turbidity	-0.1	-0.369	-.369	-0.376	1												
Cl	-0.005	0.955	0.954	0.966	-0.265	1											
SO_4	-0.019	0.712	0.711	0.716	-0.121	0.742	1										
HCO_3	-0.068	0.239	0.240	0.258	-0.552	0.123	-0.018	1									
Ca	0.136	0.954	0.955	0.949	-0.323	0.935	0.694	0.204	1								
Mg	0.140	0.946	0.946	0.929	-0.464	0.827	0.562	0.373	0.873	1							
Na	0.099	0.814	0.814	0.795	-0.160	0.809	0.757	-0.0003	0.767	0.697	1						
K	0.096	0.813	0.813	0.802	-0.134	0.850	0.767	-0.075	0.803	0.663	0.948	1					
Pb	-.202	-.317	-0.318	-.311	0.074	-0.326	-0.335	0.109	-0.353	-0.243	-0.381	-0.371	1				
Zn	-0.031	-.665	-.664	-.656	-0.007	-0.700	-0.690	0.129	-0.699	-0.556	-0.652	-0.695	0.299	1			
Cu	-.304	-.521	-.523	-.500	-.0001	-.442	-0.318	0.101	-0.526	-0.565	-0.376	-0.400	0.421	0.345	1		
Fe	-0.056	0.123	0.122	0.136	0.285	0.283	0.357	-0.334	0.205	-0.080	0.266	0.335	-0.175	-0.413	0.014	1	
Cd	-.283	-0.411	-.411	-.392	0.009	-0.457	-0.414	0.344	-.480	-0.254	-0.538	-0.570	0.459	0.471	0.258	-0.146	1

Principle component analysis (PCA)

PCA was applied to the multivariate data consisting of seventeen parameters. The coordinates of environmental variables represent the angular coefficients of the linear functions that describe the relationships between these variables and the factorial axis of the ordination. Thus, the position of the coordinate of a given environmental variable in relation to the origin (0, 0) of the diagram indicated the variation rate of these variables along each axis (Fig. 5). For the interpretation of the factorial axes, the correlations of the environmental variables with the respective axis illustrated that Zn and Cd showed the highest negative correlations with the first PCA axis. The second and fourth PCA axes showed that there are no high positive or negative correlations between the environmental variables, while the third PCA axis showed a considerable positive correlation with turbidity and iron and a negative correlation with bicarbonate. Correlation coefficients between environmental variables PCA axes are displayed in Table (11).

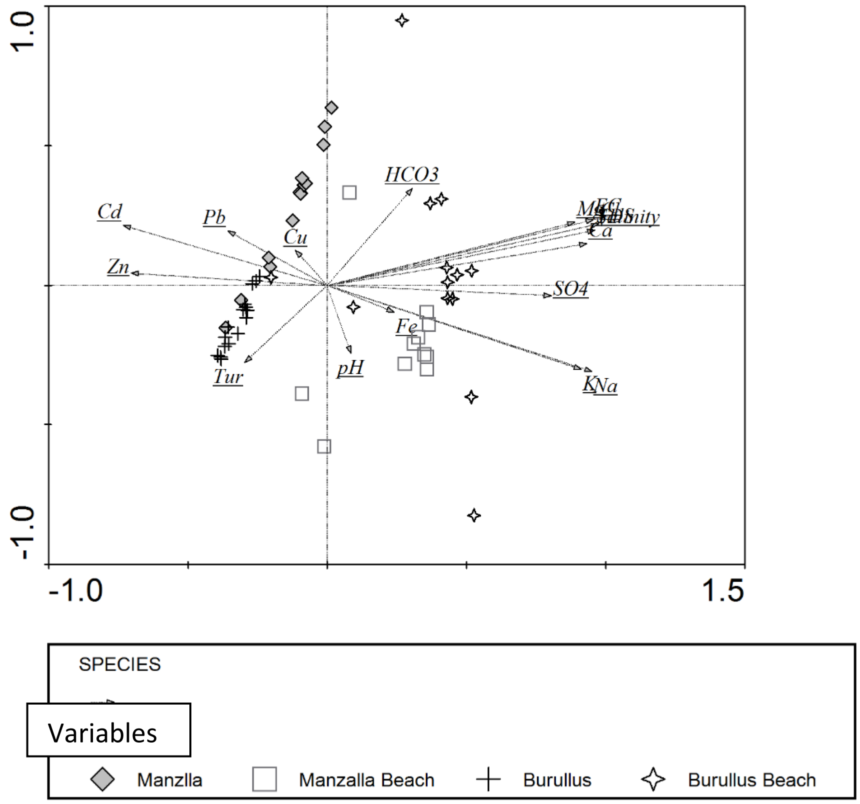

Fig. 5. Ordination diagram by PCA based on the correlation matrix of the environmental parameters

Table 11. Correlation coefficients between environmental variables PCA axes

Parameter	PC1	PC2	PC3	PC4
pH	0.0824	-0.2442	-0.1628	0.185
TDS	**0.9738**	0.1326	-0.0736	0.087
Salinity	**0.9737**	0.1324	-0.0756	0.088
EC	**0.972**	0.1881	-0.0479	0.0622
Turbidity	-0.3221	-0.2648	**0.529**	-0.0657
Chloride	**0.9677**	0.1642	0.1605	-0.0047
Sulfate	**0.7475**	-0.0874	0.2363	0.448
Bicarbonate	0.1904	0.3661	**-0.793**	-0.0866
Calcium	**0.9364**	0.1315	-0.0034	0.1871
Magnesium	**0.8796**	0.1624	-0.3314	0.1176
Sodium	**0.8969**	-0.4036	0.0513	-0.013
Potassium	**0.8946**	-0.3085	0.2012	0.0435
Lead	-0.3607	0.1771	-0.1115	-0.0528
Zinc	**-0.6999**	0.1035	-0.2556	-0.2244
Copper	-0.2248	0.0681	0.0546	-0.1362
Iron	0.1983	-0.126	**0.5501**	0.051
Cadmium	-0.6322	0.2443	-0.1741	-0.2467

CONCLUSION

The current study was performed to assess the water quality through measurements of some physicochemical properties along the northern Delta wetlands, mainly Manzala and Burullus. Water quality parameters showed a wide variation due to the discharge of drainage water from different pollution sources. The wetlands still have very bad water quality (high AWQI: 542.5, 351.9) in Manzala and Burullus wetlands, respectively, for irrigation. Moreover, the results showed that the water quality of Burullus Wetland is significantly preferable to that of Manzala Wetland, and it is the lowest wetland that meets domestic, sewage water, and industrial wastewater. Moreover, MI values revealed that both Manzala and Burullus wetlands water is suitable for irrigation (mean of MI value: 0.6 for Manzala, 0.47 for Burullus) but not for the aquatic life (mean of MI value: 16.766 for Manzala, 13.788 for Burullus).

The environmental change in the northern deltaic wetlands is very rapid and continuous, so that the assessment and management of pollution risk must also be fast and decidable. It should be taken into consideration the importance of continuous monitoring of the sediments, water, and the biological organisms in these wetlands, with a special attention to Manzala Wetland.

RECOMMENDATIONS

- An integrated management program should be implemented for the development of the wetlands and adjacent areas with periodic monitoring and assessment of water quality.
- A decentralized remote sensing and geographic information system (GIS) capability must be developed to collect and upgrade available data and to help decision-makers on local and national scales.
- A sensitivity analysis should be carried out for all coastal Egyptian wetlands to assess vulnerabilities to various problems including pollution, wetland reclamation, barrier erosion, and illegal harvesting of fry fish, etc.
- A contingency plan for protection and emergency measures must be developed. With much effort and great attention to make a proper treatment of domestic, agricultural and industrial effluents before releasing into the coastal deltaic wetlands.
- The fishermen, activities and aquaculture industries should be managed and developed through applying more modern fishing technologies, firming laws, and regulation rules.

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الملخص العربي

تقييم جودة المياه للاراضى الرطبة شمال مصر (المنزلة والبرلس) باستخدام مؤشرات جودة المياه والمعادن

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تعاني الاراضى الرطبة فى الساحل الشمالي بمصر من التلوث البيئي حيث تستقبل مياه الصرف الصناعي والمنزلي والزراعي مباشرة دون معالجة مما يؤثر سلبا على المياه باعتبارها موردا طبيعيا رئيسيا. وبالتالي فإن الهدف من هذا العمل هو تقييم مدى ملاءمة نوعية المياه في الاراضى الرطبة المنزلة والبرلس للاستخدامات المختلفة من خلال تحديد بعض المعايير الفيزيائية والكيميائية. تم جمع وتحليل ٣٢ عينة ممثلة للمياه السطحية لمعرفة درجة الحموضة، التوصيلية الكهربائية، الملوحة، المواد الصلبة الذائبة، التعكر، الكبريتات، الكلوريدات، البيكربونات، المغنسيوم، الكالسيوم، البوتاسيوم، والصوديوم، وبعض المعادن الثقيلة مثل: الرصاص، الزنك، النحاس والحديد والكادميوم. تم حساب نموذجين رئيسيين هما مؤشرات جودة المياه والمعادن (WQI، MI) لتقدير حالة جودة المياه بشكل موجز. وأظهرت النتائج أن قيم WQI في المنزلة تراوحت من ٢٣١.٠٤ إلى ٨٨٥.٧، في حين تراوحت من ١٩١.٨ إلى ٥٨٩.٨ في البرلس. علاوة على ذلك، فإن قيم MI لأغراض الري لجميع المحطات باستثناء محطتين أقل من وللحياة المائية أكثر من ١. وبالتالي، فإن جميع عينات المياه التي تم تحليلها تقريبًا من المنزلة والبرلس يمكن استخدامها للري وغير صالحة للحياة المائية. يوصى بشدة بمعالجة مياه الصرف قبل تصريفها في الاراضى الرطبة الشمالية لتتوافق مع معايير جودة المياه. بالإضافة إلى ذلك، ينبغي إجراء تقييم للموارد المائية بشكل مستمر للتخفيف من الآثار المحتملة والحفاظ على موارد المياه.