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Distribution of Nutrients P, N, and C in Burullus Wetland Sediments and Assessment of its Pollution Levels

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ABSTRACT

Burullus wetland is a vital ecological zone, recognized for its rich biodiversity. It is part of the Burullus Protected Area, which was declared a Ramsar site in 1988 because of its importance as a wetland habitat. This study evaluated the nutrient status and pollution levels of the surface sediments in Burullus wetland, Egypt. Sediment samples from thirty stations covering the area of the wetland were collected and tested for total phosphorus (TP), total nitrogen (TN), and total organic carbon (TOC) concentrations. Results indicated that TOC levels ranged from 1.33 to 4.26%, with the highest concentrations of total nitrogen (TN) and total phosphorus (TP) at sites impacted by terrestrial runoff and aquaculture zones. TN levels ranged from 0.063 to 0.404%, with maximum values observed near the agricultural runoff areas. TP content varied from 607 to 3541µg/g, with elevated levels at sites affected by anthropogenic sources, such as fertilizers and sewage. These values exceeded environmental background levels (for organic matter, TN, and TP: 1.14, 0.105, and 0.03, respectively), indicating a significant pollution.The highest concentrations of TN and TP were recorded in the eastern and central regions of the wetland, particularly in front of Drain 8, where severe pollution levels were noted. The study employed the organic pollution index (OPI) and enrichment factor (EF) to assess the extent of organic and nutrient pollution. The findings revealed severe nutrient and organic pollution in Burullus wetland, driven by agricultural runoff, aquaculture, and wastewater discharge, with a significant spatial variability across the sampling sites. Elevated levels of total organic carbon, nitrogen, and phosphorus increase the risk of eutrophication, highlighting the urgent need for pollution control measures to protect the lake's ecosystem.

INTRODUCTION

Sediment is an important component of both marine and freshwater ecosystems since it provides nutrients such as carbon, nitrogen, and phosphorus. These nutrients are critical to the mobility and transformation of biogenic components in the environment. Furthermore, sediments may absorb contaminants from the water, which helps detoxify the surrounding aquatic environment, as well as being a source of an internal pollution **(Boström *et al.*, 1988, Wang *et al.*, 2018)**.

Eutrophication in shallow significantly threatens water quality. Carbon (C), nitrogen (N), and phosphorus (P) are vital nutrients used for numerous aquatic species and play a significant role in causing eutrophication **(Hilton *et al.*, 2006, Schindler 2006)**. These nutrients may accumulate in sediments and have the potential to be released into the overlying water when environmental factors viz. temperature, pH, and redox potential vary in the sediment-water interface **(Zhang *et al.*, 2015)**.

C, N, and P are essential components of the geochemical cycle and have a close relationship with the health of aquatic ecosystems. In particular, N and P are critical limiting variables in eutrophication and are often employed as main indicators to assess the eutrophication state of reservoirs **(Wang *et al.*, 2021)**. As eutrophication becomes more prevalent in reservoirs worldwide, significant research efforts are focused on understanding the spatial distribution and influencing factors of these sediment nutrients, especially P, N, and C **(Pan *et al.*, 2023)**.

Burullus is situated at the north of the Nile Delta between the Damietta and Rosetta branches, in Kafr El-Sheikh Governorate. Covering approximately 35,000 hectares, it has an average depth of 90cm **(Younis, 2019)**. The Burullus wetland is a coastal bar that divides the Mediterranean coast in the north from the lakeshore in the south, connecting by Boughaz El-Burg to the Mediterranean Sea on the northern side **(Eid *et al.*, 2012)**. The lake is a reservoir for drainage waters polluted with anthropogenic contaminants **(El-Mamoney *et al.*, 1988)**. It receives drainage water from agricultural regions via eleven drains, as well as freshwater from the Brembal Canal, located in the lake's western side, approximately 3.9 billion cubic meters of agricultural runoff and drainage water annually from fish farms through the Birimal Canal and eight drains **(Dumont & El-Shabrawy 2007)**. The annual release of drainage water into the wetland varies from year to year, averaging around 2.5 billion m^3 per year **(Okbah 2005)**. In recent years, various researchers have explored the distribution of sediment nutrients in water and lake sediments, where nutrient concentrations vary substantially **(Lu *et al.*, 2018)**.

Burullus lake is one of the four Egyptian Ramsar sites and was named a natural protectorate in 1998 by Prime Ministerial decree number 1444, later amended by Decree No. 330/2018, including about 410km^2 of Burullus, which have significant ecological importance **(Sheta *et al*., 2023)**.

Despite its ecological value, Burullus wetland faces severe environmental challenges because of the increasing anthropogenic activities. The wetland receives drainage waters from agricultural regions via several drains, leading to contamination with fertilizers, pesticides, and other pollutants **(Hamed & Ahmed 2022)**.This influx of pollutants has impacted water quality, including an increase in freshwater prevalence, a decline in marine species, and the proliferation of hydrophytes, which indicate significant shifts in the ecological balance **(Al-Afify *et al.*, 2023)**. The increased input of drainage water loaded with agricultural fertilizers and pesticides, has significantly deteriorated its water quality and environmental functioning. These impacts include the prevalence of freshwater, decline of marine biodiversity, and the dominance of hydrophytes **(Zaghloul *et al.*, 2022)**.

Understanding the nutrient dynamics within Burullus wetland is essential for developing an effective management and conservation strategies. In particular, the distributions and quantities of C, N, and P in sediments are critical indicators of the wetland's health and the degree of anthropogenic impact. These elements are fundamental to the biogeochemical processes that sustain aquatic ecosystems, and their imbalances can lead to eutrophication, harmful algal blooms, and other environmental problems **(Bhagowati & Ahamad 2019)**. Therefore, examining the characteristics of sedimentary components is important for gaining an improved comprehension of eutrophication in Burullus wetland. This knowledge will help develop effective measures to avoid potential negative influence on the water quality of the water column above the sediment **(Li *et al.*, 2022)**.

The objective of this research was to evaluate the geographical distribution of total phosphorus (TP), total nitrogen (TN), and organic mater(OM) in the surface sediment of Burullus wetland and to assess the sediment pollution indices: enrichment factor (EF), organic pollution index method, and the comprehensive pollution index. The study employed indices such as the organic pollution index (OPI), enrichment factor (EF) and the comprehensive pollution index (CPI) to assess the pollution risk and to offer a comprehensive understanding of the wetland's present environmental condition.

MATERIALS AND METHODS

Study area

Burullus wetland is a shallow, brackish water body situated in the northern Nile Delta, between the Damietta and Rosetta branches, along Egypt's Mediterranean coast. The wetland is positioned between latitudes 31° 25′ and 31° 35′ N and longitudes 30° 31′ and 31° 05′ E **(Okbah, 2005)**. The Burullus wetland is one of Egypt's four northern lakes located along the Mediterranean Sea coast, characterized by its elongated elliptical form, as shown in **Error! Reference source not found.**).Moreover, it's located in the Nile Delta and known for its abundant fish production. Additionally, it is recognized as one of the world's internationally significant wetlands**(Dewidar 2011)**. The wetland collects runoff from agricultural, industrial, and household wastewater via eleven drains: Burullus East Drain, El-Khashah Drain, Nasser Drain (Terah), Drain 7, Drain 8 (Damro), Drain 9 (Shakhloba), Drain 11 (El Hoksa), Burullus West Drain, Zaghloul Drain, Maqsabah Drain, and Qudaah Drain. Additionally, the wetland is fed by stream from the Brimbal Canal placed in the western part **(El-Naggar & Rifaat, 2022)**(Fig 1)

Sampling and sample determination

Thirty surface sediment samples were taken from the Burullus wetland in May 2022; sampling locations were chosen to cover the whole area (**Error! Reference source not found.**). About 3kg of sediment samples were collected using a Van Veen Grab sampler. Samples were kept in a plastic bag in icebox and returned to the laboratory. The sediment samples were naturally air-dried, then sieved using a 2mm sieve to remove pebbles and branches before grinding in an agate mortar. The sediment grain size was analyzed following the method of **Folk (1974)**. The total organic carbon percent (TOC%) was determined using the method described by **Loring and Rantala (1992)**. Whereas, the organic matter (OM) was measured using the method of **Yeomans and Bremner (1988)**.

The total phosphorus (TP) in the sediment was analyzed by combustion, treatment at 550°C for 2 hours, followed by extraction with 1 N HCl for 16 hours based on the method described by **Aspila *et al.*(1976)**. After combustion, the dissolved phosphorus was calorimetrically measured, as described by **Murphy and Riley (1962)** in the sediment extracts.

The sediment's total nitrogen content (TN) was estimated using the Kjeldahl digestion technique **(Mudroch *et al.*, 1997)**. The concentrations were analyzed using the indophenol blue method, and the absorbance was measured at 630nm using a spectrophotometric technique **(Carlberg 1972)**. The technique of Kjeldahl extraction, determines the concentrations of organic nitrogen, ammonium nitrogen and was expressed as TKN% of dry biomass. All measurements are reported as total P, N, or C in μmol g^{-1} dry weight sediment, enabling the calculation of individual C:N:P molar ratios. These ratios help assess the nutrient distribution and sediment characteristics.

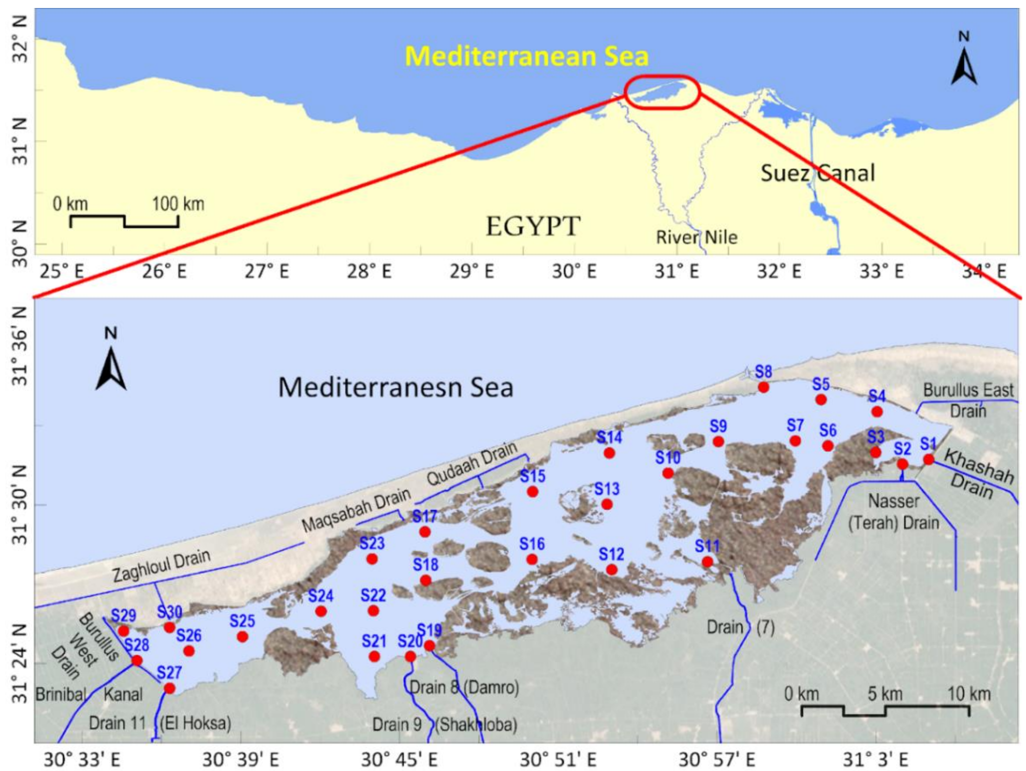

Fig. 1. The sampling sites of Burullus, Nile Delta, Egypt

Sediment contamination evaluation

To assess sediment pollution indices, we utilized various evaluation standard techniques as outlined by **Mudroch and Azcue (1995)** and **Yu *et al.*(2010)**.

The enrichment dactor (*EF*)

The $EF_i$is was calculated as per the equation of **Sakan *et al.*(2009)**:

$$EF_i = \frac{C_i}{C_{BV}} \qquad \text{Equation 1}$$

Where, $\boldsymbol{EF_i}$ is the enrichment factor for nutrient i; $C_i$is the concentration of nutrient i in the samples, and C_{BV} is the value of the environmental background for OM, TN, and TP (1.14, 0.105, and 0.03, respectively)**(**Table 1**)(Sasikala *et al.*, 2009)**, based on the calculated EF values.

Table 1. Standard values and environmental background values for sediment

	OM %	**TN %**	**TP %**	
The standard of nutrients evaluation	1.724	0.055	0.06	**(Azemared & Coquery 1997, Mudroch & Azcue 1995)**
Environmental background values	1.14 ± 0.18	0.105 ± 0.021	0.03 ± 0.003	**(Zhang *et al.*, 2015)**

Table 2. Grades of enrichment factor for nutrients in the sediment **(Mudroch & Azcue 1995; Yu *et al.*, 2010)**

EF	Grade of sediment contamination
EF < 1	no enrichment
1 < EF < 3	minor enrichment
3 < EF < 5	moderate enrichment
5 < EF < 10	moderately severe enrichment
10 < EF < 25	severe enrichment
25 < EF < 50	very severe enrichment
EF > 50	extremely severe enrichment

Comprehensive pollution index method

The comprehensive pollution index is a technique used to evaluate the extent of pollution by analyzing TP and TN levels in the wetland sediments. The formulas are provided in equations 2 and 3 below:

$$P_i = \frac{C_i}{C_s} \qquad \text{Equation 2}$$

$$FF = \sqrt{\frac{F^2 + F_{MAX}^2}{2}} \qquad \text{Equation 3}$$

Where,P_i is the single evaluation standard index; a greater value of P_i (> 1) revealed that the sediment is more contaminated by the specific nutrient. C_i is the analyzed value of factor I (mg/kg), and C_s is the standard value evaluated from factor I (mg/kg). The evaluation standard values for TNand TPwere 550 and 600mg/kg, respectively **(Mudroch & Azcue 1995; Azemared & Coquery 1997,)**, representing the concentrations of TN and TP in sediment that have the lowest environmental risk (Table 1). FF is the composite pollution index, and F is the average pollution index (average of P_{TN} and P_{TP}), while F_{MAX} is the maximum pollution index (maximum of P_{TN} and P_{TP}).

Table 3. Sediment quality benchmarks for Ontario, Canada, and the classification of comprehensive pollution degree

Nutrient	Security level	Lowest	Severe level	
TN	< 550 mg/kg	550~ 4800 mg/kg	> 4800 mg/kg	
TP	< 600 mg/kg	600 ~2000 mg/kg	> 2000 mg/kg	
OM	< 1 (%)	1– 10 (%)	> 10 (%)	
Grade	**S_{TN}**	**S_{TP}**	**FF**	**Pollution level**
1	$S_{TN} < 1.0$	$S_{TP} < 0.5$	FF < 1.0	Clean
2	$1.0 < S_{TN} < 1.5$	$0.5 < S_{TP} < 1.0$	1.0 < FF < 1.5	Mild pollution
3	$1.5 < S_{TN} < 2.0$	$1.0 < S_{TP} < 1.5$	1.5 < FF < 2.0	Moderate pollution
4	$S_{TN} > 2.0$	$S_{TP} > 1.5$	FF > 2.0	Heavy pollution

Organic pollution index method

The organic pollution index is used to evaluate pollution levels by examining the TOC and TN contents of the sediments **(Zhang *et al.*, 2015)**. Organic index (*OI*)and organic nitrogen index (*ON*) are the indicators to classify the sediment pollution and the nitrogen pollution of surface sediment in the wetlands, respectively **(Lu *et al.*, 2018)**. The formulas are described in equations 4 and 5, and the evaluation criteria are detailed in (Table 4).

$$ON = TN \times 95\% \qquad \text{Equation 4}$$

$$OI = TOC \times ON \qquad \text{Equation 5}$$

Where, ON is the organic nitrogen (%) in the sediment, and OI is the organic pollution index (Table 1). The following Table 4) represents the classification of sediment pollution levels according to the values of the organic index and the organic nitrogen index **(Yu *et al.*, 2010)**.

Table 4. Evaluation standards of organic index in sediments **(Yu *et al.*, 2010)**

Grade	I	II	III	IV
Organic Index	<0.05	0.05-0.35	0.35-0.75	≥0.75
Org-N	<0.033%	0.033-0.066%	0.066% 0.239%	>0.239%
Type	Practically uncontaminated	Uncontaminated to Moderately uncontaminated	Moderately uncontaminated	Heavily uncontaminated

Data processing and analysis

Statistical analysis and tables of the experimental data were created using Excel 2021. Additionally, significant differences in the nutrient levels in the surface sediments of Burullus wetland were analyzed, with visualizations produced using Origin 24.0 and Golden Software (Surfer 21)

RESULTS ANDDISCUSSION

The distribution of carbon, nitrogen, and phosphorus in sediments

The investigation of the surface sediments in Burullus wetland provided a visual representation of the concentrations and distribution of TOC,TN, and TP across different sampling sites covering the sampling area (Table 5 & Fig. 2.) using Surfer 21(Golden Software). The TOC levels varied significantly across the sampling sites, indicating differing levels of organic carbon, ranging from 1.33 to 4.26%, with an average of 2.72%. The maximum TOC concentrations were observed at station S18 and S29, located in front of Drain 8 and the Burullus West Drain, respectively (Table 5).

This suggests significant organic matter input, possibly from terrestrial runoff or increased primary productivity in these locations, especially the aquaculture zones (Fig. 3) **(Zhang *et al.*, 2015;Younis 2019)**. Conversely, lower TOC concentrations at stations S22 and S15 may indicate areas with less organic input. TN concentrations ranged from 0.063 to 0.404%, with an average of 0.23%. The TN levels showed variability across the sites (Table 5). The maximum TN concentrations were recorded at S22 and S30, indicative of substantial nitrogen inputs, likely due to agricultural runoff or wastewater discharge. In contrast, the lowest TN concentrations found at S14 and S20 suggest areas experiencing nitrogen limitation or efficient nitrogen cycling processes that reduce the nitrogen content in the sediments**(Huang *et al.*, 2021)**. TP content ranged from 607 to 3541µg/g, with an average of 1334µg/g. TP concentrations varied widely, with the highest value observed at site S20, in front of Drain 9 (Table 5), indicating potential phosphorus loading from anthropogenic sources such as fertilizers or sewage or fish farms contributing to eutrophication. The lowest TP value was recorded at site S14, located to the north side near the sea, suggesting areas with either limited phosphorus input or effective phosphorus retention mechanisms in the sediments **(Li *et al.*, 2016)**.

Table 5. Total phosphorus, total nitrogen, and total organic carbon in wetland Burullus

Station ID	TOC %	TN %	TP µg/g	TOM %
S1	3.77	0.298	967	6.50
S2	2.43	0.331	1445	4.19
S3	3.09	0.266	2366	5.33
S4	2.56	0.19	2899	4.41
S5	2.3	0.357	1835	3.97
S6	2.52	0.34	1835	4.34
S7	2.67	0.334	952	4.60
S8	1.85	0.174	1623	3.19
S9	2.89	0.209	1544	4.98
S10	1.96	0.177	609	3.38
S11	3.71	0.316	1543	6.40
S12	2.41	0.236	968	4.15
S13	3.27	0.187	2024	5.64
S14	3.1	0.063	607	5.34
S15	1.55	0.365	1130	2.67
S16	2.05	0.226	791	3.53
S17	1.98	0.206	778	3.41
S18	4.26	0.125	715	7.34
S19	2.39	0.105	950	4.12
S20	2.68	0.092	3541	4.62
S21	2.69	0.349	1631	4.64
S22	1.33	0.404	1362	2.29
S23	1.94	0.32	765	3.34
S24	1.85	0.248	714	3.19
S25	3.41	0.194	1024	5.88

S26	2.38	0.328	984	4.10
S27	3.42	0.379	1703	5.90
S28	3.88	0.214	1131	6.69
S29	3.97	0.19	979	6.84
S30	3.24	0.382	617	5.59
Min,	1.33	0.06	607	2.29
Max.	4.26	0.40	3541	7.34
Average	2.72	0.25	1334	4.69
SD	0.75	0.09	684	1.29

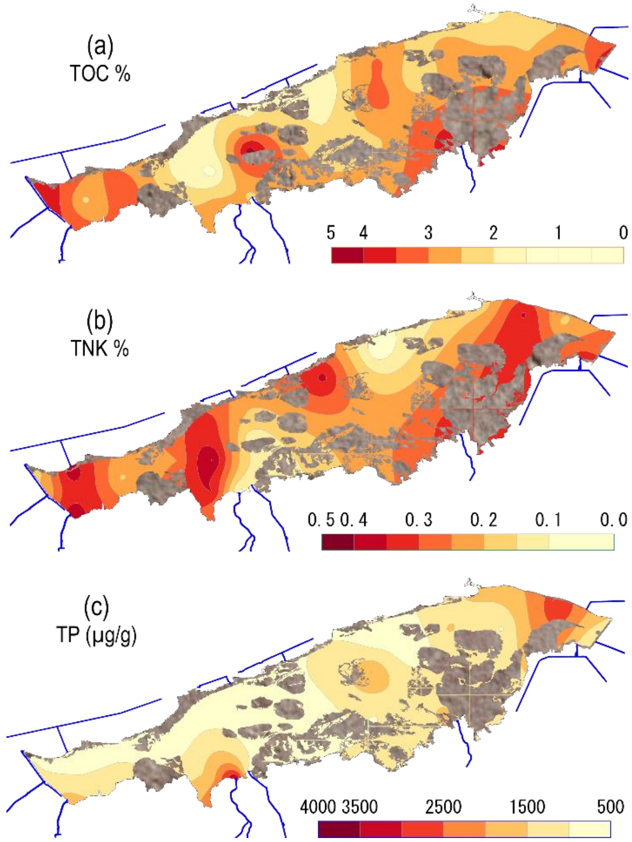

Fig. 2. Distribution of TOC%, TN% and TP μm/g

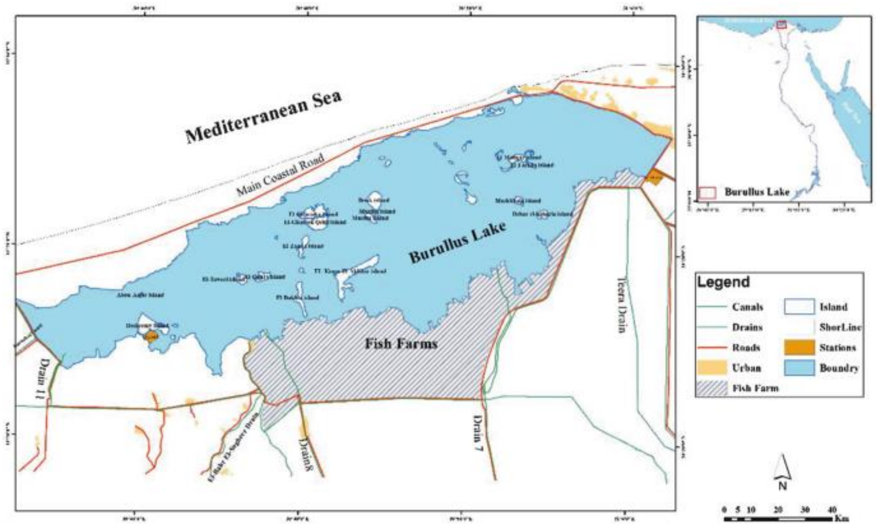

Fig. 3. Location of the fish farm according to **Younis (2019)**

Table 6. Assessment of sediment pollution and enrichment factor in wetland Burullus pollution indexes

Station ID	EF_{OM}	EF_{TN}	EF_{TP}	FF	OI	Grade	ON	Grade
S1	5.70	2.84	3.22	4.57	1.07	Severe pollution	0.283	Severe pollution
S2	3.67	3.15	4.82	5.19	0.76	Severe pollution	0.314	Severe pollution
S3	4.67	2.53	7.89	4.62	0.78	Severe pollution	0.253	Severe pollution
S4	3.87	1.81	9.66	4.50	0.46	Moderate pollution	0.181	Severe pollution
S5	3.48	3.40	6.12	5.70	0.78	Severe pollution	0.339	Severe pollution
S6	3.81	3.24	6.12	5.46	0.81	Severe pollution	0.323	Severe pollution
S7	4.04	3.18	3.17	5.08	0.85	Severe pollution	0.317	Severe pollution
S8	2.80	1.66	5.41	3.05	0.31	Moderate pollution	0.165	Severe pollution
S9	4.37	1.99	5.15	3.51	0.57	Severe pollution	0.199	Severe pollution
S10	2.96	1.69	2.03	2.72	0.33	Moderate pollution	0.168	Severe pollution
S11	5.61	3.01	5.14	5.02	1.11	Severe pollution	0.300	Severe pollution
S12	3.64	2.25	3.23	3.68	0.54	Severe pollution	0.224	Severe pollution
S13	4.95	1.78	6.75	3.39	0.58	Severe pollution	0.178	Severe pollution
S14	4.69	0.60	2.02	1.11	0.19	Mild pollution	0.060	Mild pollution
S15	2.34	3.48	3.77	5.58	0.54	Severe pollution	0.347	Severe pollution
S16	3.10	2.15	2.64	3.48	0.44	Moderate pollution	0.215	Severe pollution
S17	2.99	1.96	2.59	3.19	0.39	Moderate pollution	0.196	Severe pollution
S18	6.44	1.19	2.38	2.02	0.51	Severe pollution	0.119	Moderate pollution

S19	3.61	1.00	3.17	1.83	0.24	Moderate pollution	0.100	Moderate pollution
S20	4.05	0.88	11.80	4.96	0.23	Moderate pollution	0.087	Moderate pollution
S21	4.07	3.32	5.44	5.51	0.89	Severe pollution	0.332	Severe pollution
S22	2.01	3.85	4.54	6.21	0.51	Severe pollution	0.384	Severe pollution
S23	2.93	3.05	2.55	4.82	0.59	Severe pollution	0.304	Severe pollution
S24	2.80	2.36	2.38	3.77	0.44	Moderate pollution	0.236	Severe pollution
S25	5.16	1.85	3.41	3.11	0.63	Severe pollution	0.184	Severe pollution
S26	3.60	3.12	3.28	5.00	0.74	Severe pollution	0.312	Severe pollution
S27	5.17	3.61	5.68	5.96	1.23	Severe pollution	0.360	Severe pollution
S28	5.87	2.04	3.77	3.43	0.79	Severe pollution	0.203	Severe pollution
S29	6.00	1.81	3.26	3.03	0.72	Severe pollution	0.181	Severe pollution
S30	4.90	3.64	2.06	5.66	1.18	Severe pollution	0.363	Severe pollution
Min,	2.01	0.60	2.02	1.11	0.19		0.06	
Max.	6.44	3.85	11.80	6.21	1.23		0.38	
Average	4.11	2.41	4.45	4.17	0.64		0.24	

Sediment contamination evaluation

The enrichment factor (*EF*)

The enrichment factor (EF) is a critical measure for understanding the degree of anthropogenic impact on sediment quality by comparing the concentration of a nutrient in the sediment to its natural background value **(Mudroch & Azcue, 1995)**.

(Table 6) and Fig.2) present the EF values for TP, TN, and OM across various stations in Burullus wetland. The EF for OM ranged from 2.01 to 6.44, with an average of 4.11, indicating a significant enrichment (Table 2) due to external inputs, such as the use of fish feed in that area **(Zhang *et al.*, 2015)**. Stations S1, S11, S18, S25, S27, S28, and S29 which make up about 23% of the area, showed the highest OM enrichment with EF values above 5. This suggests substantial organic input from terrestrial runoff or increased primary productivity with moderate-sever OM enrichment near the drain area. Conversely, 23% of the stations, including S8, S10, S15, S17, S22, S23, and S24, recorded lower EF values, indicated relatively minor organic input.

Total nitrogen (TN)

The EF for TN ranged from 0.60 to 3.85, with an average of 2.41. Stations S22 and S30 exhibited the highest TN enrichment, with EF values of 3.85 and 3.64, respectively, implying significant nitrogen input likely from agricultural runoff or wastewater discharge (Fig.2). Conversely, stations like S14 and S20 showed lower TN enrichment, suggesting areas with lesser nitrogen input or efficient nitrogen cycling processes near the sea area **(Voss *et al.*, 2011)**.

Total phosphorus (TP)

The EF for TP ranged from 2.02 to 11.80, with an average of 4.08. Station S20 exhibited the highest TP enrichment with an EF value of 11.80, indicating potential phosphorus loading from anthropogenic sources such as fertilizers or sewage, which contribute to eutrophication. Other stations with high EF values for TP included S4, S13, and S5, suggesting areas significantly impacted by phosphorus input. Stations with lower TP EF values, such as S14 and S10, indicate limited phosphorus input or effective phosphorus retention mechanisms **(Li *et al.*, 2016)**.

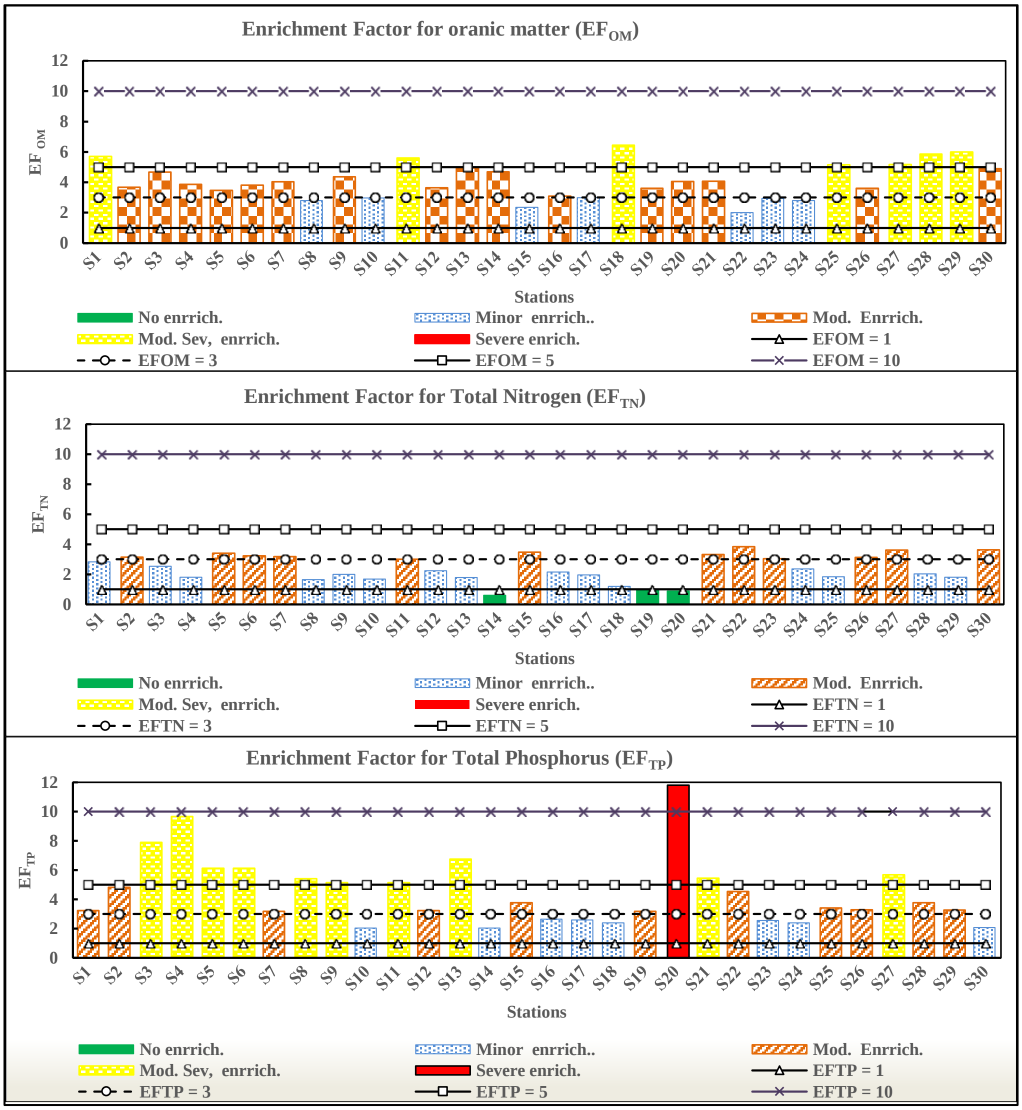

Fig.4. Enrichment factor of OM, TN, and TP in Burullus wetland

Comprehensive pollution index

The total organic carbon, nitrogen and phosphorus pollution status of the sediments of Burullus wetland was estimated according to the nutrient quality standards set by the Ontario Ministry of Environment and Energy, Canada **(Pan *et al.*, 2023)**. The results are discussed in (Table 6). The comprehensive pollution index (FF) shown in Fig.3) indicates that surface sediments at all sampled stations had an FF value greater than 2, except at stations

S14 and S19, indicating a severe pollution. The FF value for station S14 was 1.11, suggesting mild pollution, while station S19 showed a moderate pollution with the FF value of 1.83. All other sampling sites were classified as heavily polluted (Table 3). According to the lowest effect level (LEL) and severe effect level (SEL) standards, there was severe nitrogen pollution at all sampling sites, with total nitrogen concentration (TN) exceeding 550µg/g, as shown in Fig.5.). Additionally, the total phosphorus (TP) concentrations were above 660µg/g at all stations, indicating moderate pollution(Table 3). However, stations S3, S4, S13, and S20, recorded severe phosphorus pollution levels (Fig.3). The nitrogen pollution is likely caused by discharges from the surrounding drainage areas, fertilizers and fish farms, which may significantly contribute to the pollution in the wetland **(Akinnawo, 2023)**.

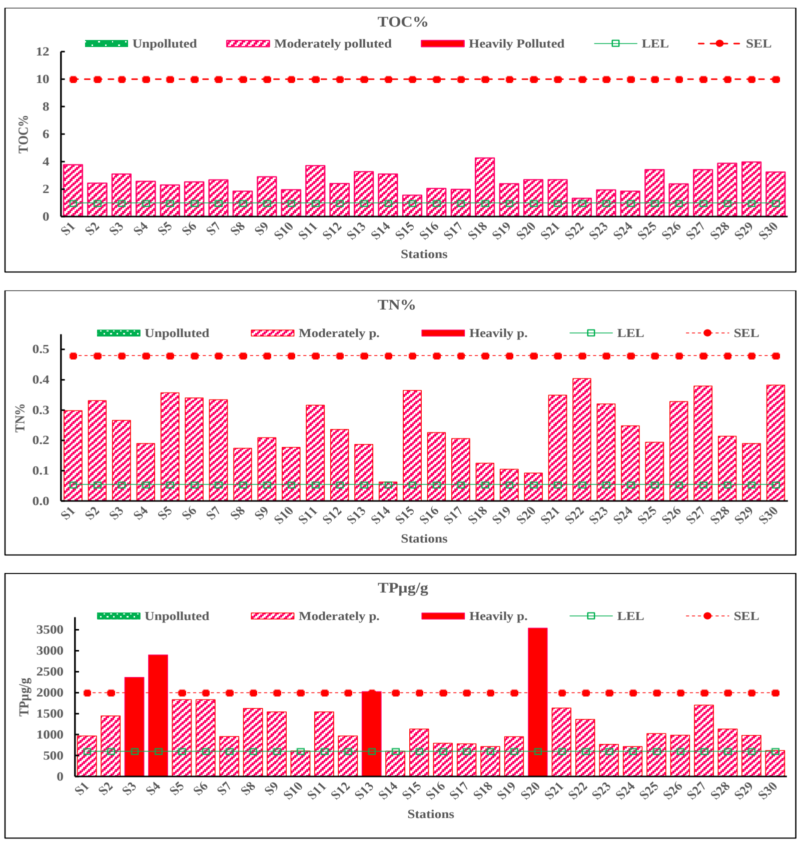

Fig.5.TOC%, TN% and TP µg/g in the studied sediment samples and their corresponding LEL and SEL concentrations values

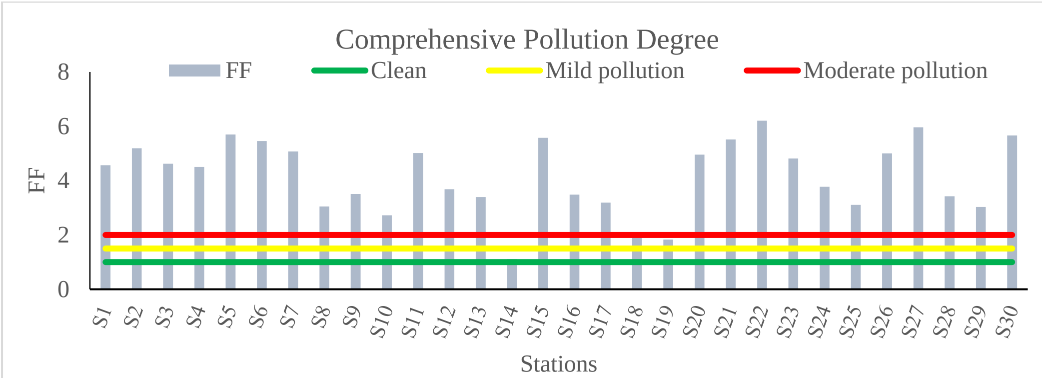

Fig.6. Distribution of comprehensive pollution degree

Evaluation of sediment pollution

Organic pollution index (OPI)

The organic pollution index (OPI) is utilized to evaluate the levels of organic pollution in rivers and lakes **(Lu *et al.*, 2018)**. This method provides an efficient means of both descriptive and quantitative assessment of organic contamination, aiding in sediment quality monitoring. The evaluation process involves measuring the concentrations of TOC and TN in sediments using the formulas (1) and (2) **(Zhang *et al.*, 2015)**. The data presented in (Table 6) indicates the levels of pollution based on the organic index (OI) and ON grades in Fig. 4). The majority of the samples show severe pollution levels for both OI and ON. The organic index (OI) range in Burullus wetland's surface sediments was 0.19–1.23, with an average of 0.64,while the ON ranged from 0.06 to 0.38% with an average of 0.24 (Table 6). Only station S14 showed a mild pollution index. The ON results follow a similar pattern, indicating severe pollution at most sites, with values exceeding 0.2 at several stations, which corresponds to severe pollution. The results indicate that the majority of the sediment samples from Burullus wetland are experiencing severe organic pollution, as evidenced by the high OI and ON values. This widespread severe pollution suggests that the lake is subject to significant organic matter input from various sources, like agricultural runoff, which introduces fertilizers and organic matter into the lake **(Okbah, 2005)**; the presence of nitrogen and phosphorus in high concentrations points to potential wastewater discharge, contributing to the nutrient load, organic pollution and terrestrial runoff. Sites near drainage outlets, such as S15 and S27, show higher pollution levels, indicating terrestrial runoff as a significant source of contamination (Elsayed et al., 2019).

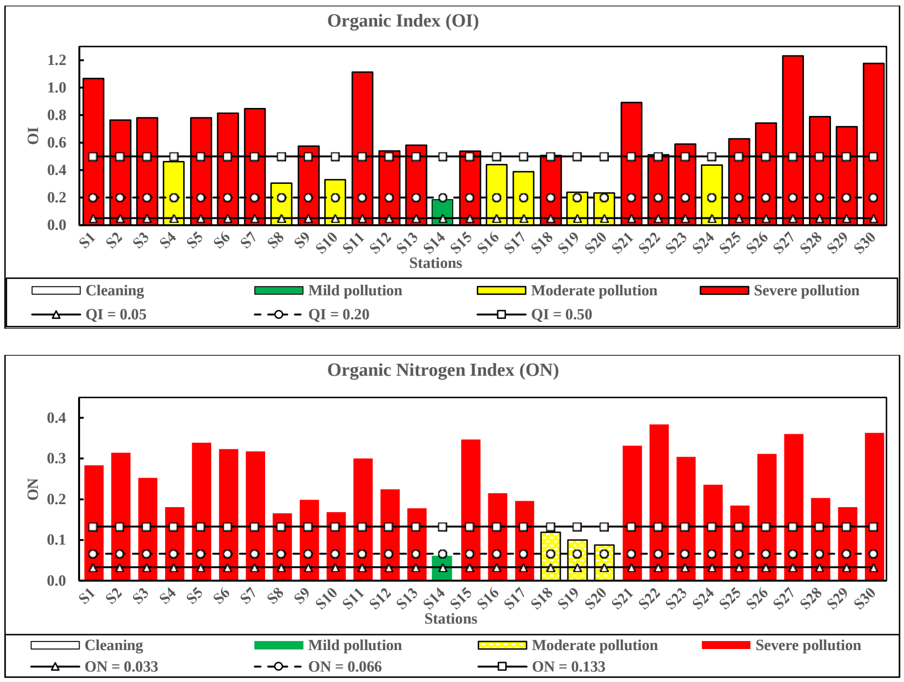

Fig. 7. Distribution of organic pollution index (OPI)

Evaluation of redfieldratio

The Redfield ratio, applied to marine environments, reflects the atomic ratio of C, N, and P, which is approximately 106:16:1. This ratio indicates a balanced nutrient composition in marine phytoplankton and has been widely used to understand biogeochemical cycles in oceanography **(Tyrrell, 2001)**. By calculating the molar quantities of TOC, TN, and TP and then determining the ratio of carbon to nitrogen to phosphorus for each station, we found that the average moles of C were 226.67mmol/g, for N they were 17.86mmol/g, and for P they were 0.043mmol/g. From that, we got the C:N ratio range from 3.84 to 57.40 with an average of 12.69 indicating highly variable nitrogen availability, and the C:P ratio range from 1955.28 to 15383.12, with an average recorded of 5273.72, showing significant phosphorus limitation in most stations. Thus, the average Redfield ratio for the dataset is approximately 12.7:1:5273.7. The average C:N ratio is 12.69, which is lower than the Redfield ratio of 6.63 (derived from 106:16). This indicates a higher proportion of nitrogen relative to carbon, suggesting possible nitrogen enrichment or lower organic carbon content in the sampled environment. While the average C:P ratio of 5273.72 is significantly higher than the Redfield ratio of 106. This indicates a much lower proportion of phosphorus relative to carbon, suggesting phosphorus limitation or very low phosphorus content in the samples.

Potential implications of redfield ratio

The high C:P ratios suggest potential phosphorus limitation in the sampled environment, potentially impacting primary production **(Jarvie *et al.*, 2018)**. Phosphorus is a critical nutrient for biological processes, and its limitation could affect the productivity and composition of the microbial and phytoplankton communities. Nitrogen limitation may be caused by intense denitrification processes **(Doering *et al.*, 1995)**. The variation in C:N:P ratios might be influenced by local environmental conditions such as pollution, runoff, agricultural activities, or natural processes that affect nutrient availability **(Wang *et al.*, 2022)**.

CONCLUSION

This study assessed the nutrient status and organic pollution levels of surface sediments in Burullus wetland, providing a detailed analysis of contamination patterns and their sources. The findings highlight a significant spatial variability in nutrient concentrations, primarily driven by agricultural runoff, aquaculture activities, and wastewater discharge.

High levels of total organic carbon (TOC), particularly at stations S18 and S29, indicate substantial organic matter input from terrestrial runoff and aquaculture zones. Elevated total nitrogen (TN) at sites S22 and S30, along with the high otal phosphorus (TP) at site S20, suggest significant nutrient contributions from agricultural runoff and wastewater. The organic pollution Iindex (OPI) revealed severe organic pollution across most sampling sites, corroborated with the high organic index (OI) and organic nitrogen (ON) values. Enrichment factor (EF) analysis categorized sediment contamination as severe and very severe enrichment grades, underscoring the heavy nutrient influx from the surrounding drainage areas. The comprehensive pollution index (CPI) confirmed these findings, indicating heavy pollution at most sites, while the functional pollution 9ndex (FF) indicated severe nitrogen and phosphorus pollution at nearly all sampling sites, surpassing thresholds for severe pollution.

The presence of high TN and TP concentrations, coupled with significant organic matter input, highlights the profound impact of anthropogenic activities on Burullus's ecosystem. These high nutrient levels can lead to eutrophication, degrading water quality and affecting aquatic life.

Urgent measures are needed to prevent further negative impacts by implementing robust pollution control strategies. Regular monitoring of sediment quality, controlling agricultural runoff, and improving wastewater treatment processes are essential to reduce nutrient inputs and enhance the resilience of this vital aquatic ecosystem.

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