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Assessment of Water and Sediment of El Qalyubia Main Drain, East Delta, Egypt

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ABSTRACT

Water pollution is of great concern due to environmental and health impacts. Chemical and biological quality of wastewater may be affected by anthropocentric activities such as industrial, urban, and agricultural activities. El Qalyubia drain is responsible for transporting polluted water from irrigation runoff and domestic and industrial sewage. Objective of this study was to assess the quality of both water and sediment throughout summer and winter (2022 & 2023). Water and sediment samples were obtained from eight locations alongside a drainage system and were analyzed for various chemical and microbial parameters. The findings were then evaluated against the recognized standard for wastewater. The findings differed among different locations due to types of waste generated from various activities occurring near El Qalyubia drain. Study indicated that certain chemical and biological components including total solids, total suspended solids, dissolved sodium percentage, organic pollution index, comprehensive pollution index, pollution factor, hydrocarbons, and phenol exceeded recommended limits for wastewater. However, other parameters such as total dissolved solids, pH, EC, chloride, magnesium (total hardness and Pathogenic indicators) were found to be within acceptable standards. According to water and sediment quality index, industrial, urban, and agricultural activities have been shown to have an impact on water and sediments. As a result, it is essential to treat wastewater to eliminate pollutants in order to safeguard the environment and public health. This study is crucial as it directly contributes to achieving clean Water and Sanitation by improving water quality, reducing pollution, and ensuring sustainable water management for all.

Keywords: water and sediment quality index; chemical; organic pollution; biological parameters

INTRODUCTION

Water is the most important substance for human being and living organisms, (Meilina and Ramli 2021). The increase in waste production in the water shed due to population growth and other human activities will lead to a decline in water quality. Human activity has significant impacts on the quantity, quality, and chemical characteristics of water supplies (Akhtar et al., 2021). Various chemical factors, including conductivity, pH, chemical oxygen demand (COD), total suspended solids (TSS), biological oxygen demand (BOD), total dissolved solids (TDS), and heavy metal concentrations, also influence water quality (Maritim et al., 2022). When trash is discharged into drains through urban runoff, it is expected to contribute to sediment pollution (Khan et al., 2021). The high concentration and accumulation of heavy metals result in loss of biodiversity in the marine ecosystem, affecting the quality of sediments and aquatic food sources. Sediments, which can contain pollutants, are a crucial indicator of water quality (Tepe and Ustaoğlu 2019). The Water Pollution Index (PI) serves as a measure for controlling water quality. Sediment quality guidelines offer comparative values to assess contamination risk in aquatic environments, (Birch 2018). Alterations to the chemical composition of water due to pollution can have adverse effects on the ecosystem, wildlife, and human health (Zare et al., 2021). Reusing contaminated water in agriculture poses significant challenges and restrictions, requiring a rationalized approach based on water quality and the development of suitable management and protection strategies for this unconventional resource. In many developing nations, farmers often use industrial and municipal effluents to irrigate their crops. The use of untreated or partially treated wastewater for irrigation raises concerns related to health and the bioaccumulation of harmful chemicals, leading to environmental and medical issues (Abuzaid and Jahin 2021).

Thus, the assessment of water quality is essential in preventing potential hazards (Zhang et al., 2020). Industrial, agricultural, and municipal wastewater discharge has caused damage to the soil irrigated by El Qalyubia drain water. This study primarily focuses on the water quality of irrigation from El Qalyubia drain to evaluate the extent of water pollution globally. The main goal of this study was to chemically and biologically assess the water and sediment quality in El Qalyubia drains to determine their suitability for irrigation. Water samples from eight locations were collected and qualitatively analyzed using various criteria to determine the suitability of the water for irrigation.

MATERIALS AND METHODS

Description of the study area

El Qalyubia main drain is drainage system carrying contaminated water resulted from irrigation return flow, domestic and, industrial waste. The primary drainage system in Qalyubia is used to move irrigation water flow and

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contaminated water from home and industrial trash. This drain measures roughly 72 km in length, 30 m in width, and, 1 to 3 m in depth. The research area crosses the governorates of Qalyubia and Sharkia between latitudes 30° 15' 32.461" to 30° 28' 57.027" north and longitudes 31° 8' 51.061" to 31° 21' 3.166" east. Eight locations totaling roughly 47 kilometers were considered in this study: two in the Sharkia and, six in Qalyubia governorates. As indicated in Fig. 1 and Table 1, water samples were collected from eight locations.

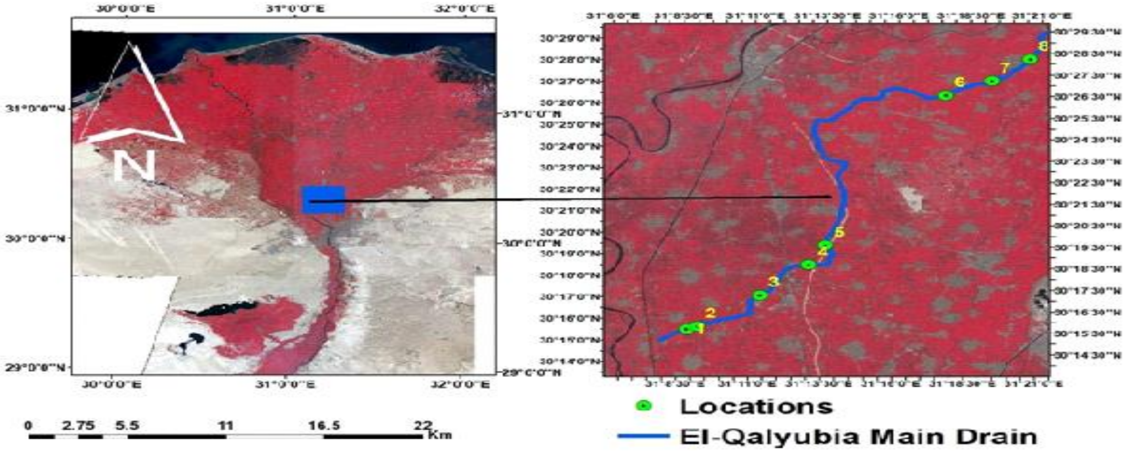

Fig. 1. Map of the study area's sampling locations.

Table 1. Sampling sites along El Qalyubia main drain

Sites	Name	governorate	Longitude	Latitude
1	Beginning of drain line No. 12, Road Al-Qanater- Banha	El Qalyubia	31° 8' 51.061" E	30° 15' 32.461" N
2	Sundbess Kafr As-Sabil drain		31° 9' 12.240" E	30° 15' 40.500" N
3	Izbat Abd as Salam Shadid		31° 12' 33.554" E	30° 18' 34.343" N
4	Izbat Abo Shienaf		31° 14' 1.238" E	30° 22' 36.879" N
5	Izbat El-Ammarna		31° 14' 24.018" E	30° 26' 6.119" N
6	Kafr ATA Allah		31° 17' 41.183" E	30° 26' 31.438" N
7	As Sanafin Al Qibliyyah	El Sharkiya	31° 19' 16.543" E	30° 27' 12.985" N
8	Sanhut Al Birak		31° 21' 3.166" E	30° 28' 57.027" N

Water sampling and analysis

In The summer of 2022 and the winter of 2023, water samples were collected from eight locations along the El Qalyubia main drain. According to Duncan *et al.,* (2007), water samples were taken from every location in high-density polyethylene bottles that had been previously cleaned and packaged. Before being analyzed, the samples were kept at 4°C in an ice tank that was brought to the lab. According to Estefan (2013) and Clesceri *et al.,* (1998), the soluble heavy metals in water samples were analyzed for EC, pH, and anions and cations.

Sediment Sampling and analysis

Samples of sediment were taken at each site then kept in plastic bags. The samples were placed in the labeled polythene after being air dried and sieved through a <0.2 mm screen, (Lei *et al.,* 2008). Lindsay and Novell (1978) determined the constituents of HMs and the available macronutrients. Additionally, the biological factors governing whether the waters under consideration are suitable for irrigation. According to IOC (1984) and Box (1983), total hydrocarbons, including total phenol, were recovered from wastewater and sediment samples. Water and sediment samples were analyzed for biological indicators in order with APHA (1982).

Water quality index

- Calculate in following the USDA (1954), Soluble sodium percentage (SSP) has been calculated using the equation: SSP = $(Na^+ \times 100) / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)$, where all ions are represented in $mmol_cL^{-1}$.
- The calculation of the amount of Total hardness (TH) was described by Twort *et al.,* (1994) as follows: TH = $(Ca^{+2} + Mg^{+2}) \times 50$, where the equivalent weight of calcium carbonate and TH is expressed as mgL^{-1}, and the quantities of Ca^{2+} and Mg^{2+} are expressed in $mmol_cL^{-1}$.
- Calculation Mg hazard = $Mg^{2+} / (Ca^{2+} + Mg^{2+}) \times 100$, where concentrations of Ca^{2+} and Mg^{2+} are expressed in $mmol_c L^{-1}$.
- Calculations of organic pollution index (OPI) as shown by Zhou, *et al.,* (1983):

$$\mathbf{OPI = (BOD/BOD_s) + (COD/COD_s) + (NO^-_3/NO^-_{3s}) + (PO^{2-}_4/PO^{2-}_{4s}),}$$

where:

(S) represents to permissible limits in the quality of wastewater for irrigation according to WHO, (2006) and all concentrations are expressed as mg.L$^{-1.}$

- Calculations of water pollution with HMs was assessed based on the calculations of Yan *et al.,* (2022) as follows: pollution index (PI): PI = C_i / C_p where; C_i is metal content in water; C_p, the permissible limits of metals in quality of wastewater for irrigation according to FAO, (2017), and all concentrations are expressed as mgL^{-1}.Calculations of comprehensive pollution index (CPI) following equation are as described by Yan *et al.,* (2022):

$$\mathbf{CPI = 1/n \, \Sigma \, PI,}$$

where

n: parameters number. Table 2 presents the wastewater quality status classification and irrigation suitability.

Sediment quality index

The degree of contamination index, also known as the contamination factor Cf, was used to characterize the presence of a particular hazardous element in sediment.

$$\mathbf{Cf = Ce/Cb,}$$

Häkanson (1980) discovered that Cf values represented the background reference concentration values of the different metals, C background, and the measured metal concentration of the sediment sample, C metal. These were in reference to the background levels of 5, 1, 1.5, 0.05, 0.5, 0.01, 1, 5, and 0.01 $mgkg^{-1}$, for Fe, Mn, Zn, Cu, Cd, Co, Pb, Ni, and Cr, respectively.

Table 2. Classification of water quality indexes and references.

Parameters	Unit	Category	Description	References
Total Solids (TS)	mgL^{-1}	1500		WHO, (2006)
Total suspended solids (TSS)		60		
Total dissolved solids (TDS)		1500		
Salinity hazard (EC)	dSm^{-1}	<1	very good	FAO, (2017)
		1-2	medium (good)	
		2-4	high (marginal)	
		4-6	very high (harmful)	
		> 6	very harmful	
chloride hazardous	mgL^{-1}	< 142	Non-problem	
		142 – 355	Slight-moderate	
		> 355	Sever	
Percentage of dissolved sodium (SSP)	%	< 20	Excellent	USDA, (1954)
		20-40	good	
		40-60	permissible	
		60-80	doubtful	
		>80	unsuitable	
Total hardness (TH)	mgL^{-1}	0–60	soft	EPA, (1986)
		60–120	moderately hard	
		120–180	hard	
		> 180	very hard	
Magnesium hazard	%	< 50	Excellent	Staff, USL, (1954)
Organic pollution index (OPI)	mgL^{-1}	<0	excellent	Shakir *et al.*, (2017)
		0–1	good	
		1–2	being to be contaminated	
		2–3	lightly polluted	
		3–4	moderately polluted	
		4–5	heavily polluted	
Comprehensive pollution index (CPI)		0–0.2	clean	
		0.21–0.4	sub clean	
		0.41–1.0	slightly polluted	
		1.01–2.0	moderately polluted	
		>2.0	severally polluted	

RESULTS AND DISCUSSION

Water Quality Indexes:

1-Chemical parameters

1. Total solids (TS)

The TS present in water consist of dissolved solids, suspended solids, and settleable solids. The findings from the study indicate that the TS levels in the El-Qalyubia main drain are significantly influenced by seasonal variations, specifically during the summer and winter seasons. In summer, the TS values range from 200 to 3600 mgL^{-1}, while in winter, they range from 880 to 4880 mgL^{-1}. The corresponding averages for these seasons are 1450 and 1650, respectively. It is worth mentioning that the TS values for all sampling sites fall within the permissible limit of 1500 mgL^{-1} (as defined by FME in 2015), except for sites 4 and 7 during the summer and sites 1 and 7 during the winter. This observed increase in TS levels can be attributed to the influx of sewage, fertilizers, and runoff from roads into the main drain.

2. Total Suspended Solids (TSS)

The TSS) indicator refers primarily to inorganic salts and a limited amount of organic matter that are dissolved in water, as stated by Ustaoğlu et al. (2020). In Table 3, we can find a classification of irrigation water based on TSS values. It is noteworthy that during the summer season, TSS ranged from 110 to 3112, while in the winter season, it varied from 65 to 4849. These values clearly indicate that all TSS measurements exceeded the permissible limit set by the World Health Organization (WHO) in 2006. The elevated TSS levels are primarily attributed to suspended solids that originate from the upstream area and are insoluble. These solids accumulate in the El-Qalyubia main drain. The excessive concentration of TSS in irrigation water samples can cause detrimental effects, such as the formation of a surface shell that hinders water percolation into the soil and impacts soil aeration, as highlighted by Aliyan et al. (2024). It is crucial to address these concerns in order to maintain the quality and productivity of the irrigated land.

3. **Total dissolved solids (TDS)**

The TDS indicator denotes the presence of inorganic compound ions in water, originating from various sources such as domestic waste, industrial waste (such as detergents), or natural water containing chlorides, bicarbonates, fluorides, sulfates, and other ions (Hadi et al., 2019). The average TDS values for all locations were found to be within the permissible limit of 1500 mgL^{-1} (as shown in Table 2). Seasonal variation in TDS revealed the highest value in summer (1178 mgL^{-1} at site 4) and the lowest in winter (90 mgL^{-1} at site 1). During winter, the higher TDS concentration (1234 mgL^{-1} at site 7) could be attributed to reduced photosynthetic activity due to the death and decay of macrophytes, leading to the accumulation of salt ions in the water. Conversely, the lower concentration during summer may be due to a high macrophyte cover promoting sedimentation and preventing the suspension of sediment particles, therefore restricting the release of nutrients from the sediment (Bashir et al., 2020).

4. pH

The quality of irrigation water is evaluated using pH as an indicator parameter. According to Bortolini *et al.*, (2018), the presence of organic and/or inorganic contaminants is indicated by irrigation water with low pH values or excessive acidity/alkalinity. Results Table 3 show that during the summer and winter seasons, the pH of El-

Qalyubia main drain is affected slightly by the seasonal change, where pH ranged from 7.7 to 7.9 in summer and 7.87 to 7.99 in winter with averages of 7.8 and 7.86, respectively. These results suggest that during both seasons the wastewater is overall in the neutral range in both seasons. Comparison of the pH values with the normal range of standard irrigation water 6.0-8.4, showed that the samples are within the range for irrigation water use for all locations and in two seasons. The pH values also, influenced by the properties of the soil and sediment particles, and also, by environmental factors (Akhtar *et al.,* 2021).

5. Salinity and chloride hazards

This indicator is considered as an important factor when assessing the water is suitable for irrigation. In this study, the average values of EC and Cl^- were (1.23 dSm^{-1} and 214.53 mgL^{-1}) respectively, in summer season, and 1.53 dSm^{-1} and 225.17 mgL^{-1} respectively in the winter (Table 3). According to FAO, (2017) the restriction on use the water of El Qalyubia main drain is relevance, as EC< 2 dSm^{-1} and Cl^- <350 mgL^{-1}. The values of EC were medium in all location during the study period. All the Cl^- concentration values during the study period showed similar trend of EC values. Furthermore, winter mean values were greater than summer mean values, indicating that precipitation and the dissolution of minerals containing chloride may be the sources of chloride, whereas heavy fertilizer use may be the source of anthropocentric sources (Akhtar *et al.,* 2021).

6. Sodality Hazard (Soluble sodium percentage, SSP).

The SSP is a key parameter for assessing agricultural water quality (Sarker *et al.,* 2000). Results indicate that it ranged from 51.02 to 61.63% in summer season and, and 59.01 to 63.66 % in winter season. Water with high percent of SSP will cause sodium accumulations that will lead to breakdown of the soil properties. From these data, it is observed that, the calculated SSP values for all seasons and all locations showed that, such water is not recommended for irrigation purposes. It will cause destruction of soil structure, (Moghadam et *al.,* 2015).

7. Magnesium hazard

Mg- hazard is used to assess the suitability of water for irrigation use, (Muthu *et al.,* 2024). High index of magnesium hazard value (> 50%) in irrigation water has an adverse effect on the crop yield as the soil becomes more alkaline. Mg- hazard is also, considered a concomitant factor to the evaluation of irrigation water suitability as it can deteriorate the soil quality when its value in the water system exceeds 50. During the summer season, magnesium ratio varied between 37.71 to 48.85 and 39.25 to 48.98, with a mean value of 43.65 and 44.43 (Table 3); in the summer and winter season, respectively. No difference seasonal was observed in the value of magnesium ratio throughout the two seasons. Suggested magnesium ratio for irrigation water is 50 (critical limit), it was still below the threshold for the quality standard water for all locations. Based on the results, the water samples are less than 50 and thus they are safe and suitable to be used for irrigation purposes.

8. Total Hardness (TH):

TH is defined as the sum of Ca & Mg cation concentrations reported in mgL^{-1} (WHO, 2006). CO_3^{2-} and HCO_3^- concentrations play an important role in determining the suitability for irrigation water, as the carbonate concentration exceeds the total concentration of calcium and magnesium exceeds, with a high excess of residual carbonate. Excess carbonate ions react with cations (Ca^{2+} & Mg^{2+} ions) to form a solid that precipitates out of the water and the relative abundance of sodium increases, leading to deteriorating consequences for plants. These findings agree with (Zaman et al., 2018) who reported that when the soil solution concentrates under drying circumstances, bicarbonate and carbonate ions coupled with calcium or magnesium precipitate as $CaCO_3$ or $MgCO_3$. He also added that when Ca^{2+} and Mg^{2+} concentrations fall below those of Na^+, the SAR index rises, resulting in an alkalizing action and a rise in pH. These consequently reduce water permeability and have a deterioration impact on the soil structure. Table 3 indicated that TH of water samples varied from 202 to 238.5 mgL^{-1} in summer and 232.5 to 268.5 mgL^{-1} in winter season in sites (5 and 7), respectively. It is clear that high value of TH of water samples was in site (7) is due to human activities around El-Qalyubia main drain; sewage and agriculture or because this sampling site is very close to urban area so all municipal sewage discharged. There. All studied sites were higher than highest desirable limit for discharge (> 180 mgL^{-1}, sea Table 2). Thus, the result suggests that most of the water samples represent a problem when using irrigation systems. Elimination of the hardness is essential for wastewater to be reused. The research data showed that the previous index calculations for TH suggest that there is tendency for Ca & Mg to precipitate with carbonate and bicarbonate in the soils irrigated by the water. This caused increased in sodium hazard and its related problems in the area. Also, the TH was a vital issue of water quality agricultural purposes, (Muthu *et al.,* 2024). Irrigation water with high value of the TH effects soil organic matter decaying. Also, it causes clay dispersion which ultimately causes poor soil permeability and the infiltration movement of water through the soil will become very slowly, (Butche*r et al.,* 2016).

9. Comprehensive pollution index (CPI) of water samples:

The CPI is evaluated by using measured parameters with respect to their permissible limit in irrigation water results shown in Fig. 2 and Table 4. The CPI was found to be in the category of slightly polluted water quality (CPI values 0.41–1.0) during both two seasons and at all sites. It is observed that the calculated CPI was found to be higher in summer season than in winter season at all locations. It indicates that the drain receives more amount of wastewater in the summer season and has less dilution of water, (Mishra, 2016). CPI results were found to vary in the range 0.549–1.379, whereas average CPI was found as 0.964 in summers and in range 0.061-0.922, whereas the average CPI was found as 0.492 in winter. This indicated to slightly polluted (0.41–1.0) in all sites. Comparisons between summer and winter data suggest that, water temperature is an important factor for microbial activity. It is suggested that increasing the rate of air changes per hour in summer would be beneficial to reduce the concentration of bio aerosols during this time of the year. CPI values varied among sampling sites, implying that all sampled sites experienced different levels of pollution. However, the highest CPI was recorded at the sampling site 1, (1.379) in summer, and 7, (0.922) in winter. Increased water temperature may enhance the degradation of organic matter, and facilitation of dissolved trace metals which was the dominant source factor responsible for the change in wastewater quality, (Anh, *et al.,* 2023). The drain also receives heavy agricultural runoff that discharges trace minerals. Therefore, on the basis of the results obtained, it was found that wastewater is suitable for irrigation, but it limits its suitability for irrigation, especially in soils with limited drainage. These findings agree with (Son *et al.,* 2020). Who stated that the CPIs were different among the monitoring sites upstream, midstream and downstream. The midstream had lower (CPIs= 0.95-1.37) during the monsoon period in comparison to the dry season (CPIs= 1.02-1.57).

Table 3. Chemical characteristics of the investigated water samples summer and winter seasons.

Sites	TS	TSS	TDS	pH	EC dS.m^{-1}	Na	K	Ca^{2+}	Mg^{2+}	Cl^{-}	HCO$_3^{-}$	TH	SSP	Mg-hazard
		mgL^{-1}							mgL^{-1}					
								summer						
1	200	110	90	7.80	1.12	164.91	12.51	46.49	21.64	183.68	122.20	205.00	61.86	43.41
2	1300	554	746	7.70	1.27	186.53	15.64	51.10	20.92	228.01	122.20	213.50	63.46	40.28
3	1400	1213	187	7.80	1.33	192.05	16.03	53.51	22.25	268.79	122.20	225.00	62.97	40.67
4	1700	522	1178	7.90	1.40	209.53	18.38	48.90	27.85	289.35	122.20	236.50	63.66	48.41
5	1000	437	563	7.80	1.06	144.67	12.51	46.49	21.04	139.71	122.20	202.50	59.01	42.72
6	1100	142	958	7.80	1.12	149.5	12.51	52.30	19.21	187.23	122.20	209.50	59.04	37.71
7	3600	3112	488	7.80	1.31	186.53	11.73	48.90	28.33	224.82	122.20	238.50	61.53	48.85
8	1300	1095	205	7.90	1.19	164.91	14.08	47.70	25.78	149.64	122.20	225.00	59.60	47.11
Aver.	1450	898.13	551.88	6.84	1.09	156.14	12.61	42.886	20.976	185.500	106.925	219.44	61.39	43.65
SD	972.4	978.67	390.17	0.06	0.12	21.89	2.23	3.29	3.33	50.71	5.09	12.97	1.82	3.84
							winter							
1	4880	4849	31	7.99	1.42	193.43	24.24	52.50	25.29	194.32	140.53	235.00	61.25	44.26
2	1040	99	950	7.80	1.67	198.95	27.37	57.11	24.56	238.65	140.53	243.50	60.83	41.48
3	880	105	775	7.87	1.63	216.43	27.76	59.52	25.90	279.42	140.53	255.00	61.83	41.76
4	1200	269	931	7.80	1.70	151.57	30.11	54.91	31.49	299.99	140.53	266.50	51.93	48.59
5	1160	143	1017	7.83	1.36	156.4	24.24	52.50	24.68	150.35	140.53	232.50	56.34	43.66
6	1200	92	1108	7.90	1.42	193.43	24.24	58.32	22.86	197.87	140.53	239.50	60.85	39.25
7	1600	366	1234	7.79	1.61	171.81	23.46	54.91	31.98	235.45	140.53	268.50	55.58	48.98
8	1240	65	1175	7.86	1.49	161.13	25.81	53.71	29.43	160.28	140.53	255.00	51.02	47.45
Aver.	1650	748.5	902.63	6.87	1.36	180.38	22.87	48.15	24.17	194.81	122.96	249.44	57.45	44.43
SD.	1332.	1572.1	457.62	4.37	61.32	23.34	4.93	4.85	3.81	51.37	11.20	16.38	4.29	3.37

SD: Standard deviation (statistically significant coefficients p < .05).

Table 4. Comprehensive pollution index (PI) of the investigated water samples summer and winter seasons.

Sites.	Fe	Mn	Zn	CU	Cd	Co	Pb	Ni	Cr
					summer				
					mgL^{-1}				
1	0.169	4.125	0.021	0.027	4.000	Nd	0.520	3.445	0.100
2	0.158	2.395	0.111	0.007	1.300	Nd	0.002	0.865	0.100
3	0.149	2.290	0.104	0.024	1.000	Nd	0.002	1.670	0.100
4	0.111	1.800	0.054	0.017	2.000	0.020	0.414	1.880	0.100
5	0.144	0.895	0.004	0.007	1.300	Nd	0.410	8.105	0.100
6	0.137	1.525	0.004	0.006	3.700	Nd	0.049	0.865	0.100
7	0.128	1.530	0.003	0.040	2.100	Nd	0.088	4.780	0.100
8	0.081	1.140	Nd	0.003	8.400	Nd	0.002	0.200	0.100
Aver.	0.125	2.51	0.055	0.022	4.7	0.01	0.261	4.152	0.100
SD.	0.03	1.01	0.05	0.01	2.02	0.01	0.22	2.64	0.00
				winter					
1	0.189	0.553	0.021	0.027	0.000	Nd	0.520	Nd	Nd
2	0.178	0.518	0.111	0.007	0.000	Nd	0.002	Nd	Nd
3	0.151	0.270	0.104	0.024	0.000	Nd	0.002	Nd	Nd
4	0.164	0.018	0.054	0.017	2.000	0.600	0.414	0.001	0.200
5	0.177	0.020	0.004	0.007	Nd	Nd	0.410	Nd	Nd
6	0.149	1.525	0.004	0.006	Nd	Nd	0.049	Nd	Nd
7	0.141	1.530	0.003	0.040	6.500	Nd	0.088	Nd	Nd
8	0.170	1.140	0.000	0.003	Nd	Nd	0.002	Nd	Nd
Aver.	0.165	0.774	0.055	0.022	3.25	0.30	0.266	0.0005	0.1
SD.	0.02	1.00	0.05	0.02	2.12	0.01	0.23	0.01	0.01

SD: Standard deviation (statistically significant coefficients p < .05),Nd: not detected.

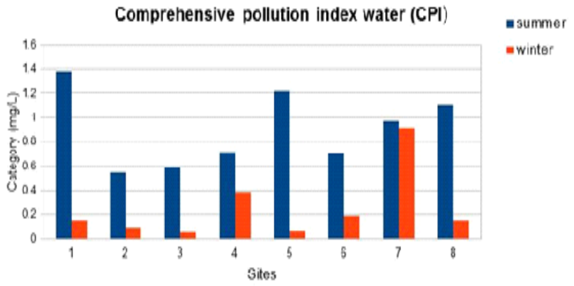

Fig. 2. Comprehensive pollution index water (CPI) of the investigated water samples summer and winter seasons.

Organic indicators

1. Organic pollution index (OPI)

Dissolved oxygen, chemical oxygen demand and biological oxygen demand are important water quality indicators, (Matta *et al.*, 2020). Organic pollution index values are usually expressed in terms of BOD, COD, PO$_4^{-2}$, NH$_4^{+}$ and NO$_3^{-}$ to quantitatively assess the impact of industrial and human increases in organic pollution in the aquatic environment, and their scale are shown in Table 5 and Fig. 3. The OPI values were characterized at locations with different values. Seasonal variations were calculated for two periods, summer and winter. It was observed that OPI values at the study locations varied from the lowest values (1.39 and 4.02) to (5.88 and 24.57) in summer and winter, respectively.

Thus, El-Qalyubia drain was classified as lightly polluted, moderately polluted, and heavily polluted during the summer. The OPI showed very severe pollution at all locations during the winter period. This explains because organic pollutants discharged directly into drains without any treatment have such serious effects. Since aquatic plants and phytoplankton consume more nutrients in summer than in winter, OPI values are lower in summer. These results are dependable with those of Makki *et al.,* (2023) and Son *et al.,* (2020).

Table 5. Concentration of BOD, COD, Nitrate, and Phosphate at summer and winter.

Sites	PO_4^{2-}	NH_4^+	NO_3^-	COD	BOD
	Summer				
	mgL^{-1}				
1	0.077	4.33	3.12	7.14	4.67
2	0.087	5.27	4.90	16.00	10.79
3	0.079	8.09	7.02	8.00	5.83
4	0.086	10.09	8.90	12.00	7.92
5	0.073	7.78	5.09	8.08	6.19
6	0.072	3.9	2.40	4.00	2.67
7	0.079	20.78	10.08	8.00	5.53
8	0.093	13.67	8.99	4.00	2.13
Aver.	0.081	12.56	6.24	10.0	6.46
SD.	0.007	5.674	2.867	3.990	2.780
	Winter				
1	1.087	5.30	4.12	52.00	33.41
2	1.097	6.99	5.90	50.00	33.83
3	1.099	9.99	8.09	57.14	43.37
4	1.076	12.09	9.90	78.57	56.41
5	1.073	8.78	6.09	28.57	23.81
6	1.072	5.90	3.40	21.43	17.93
7	1.079	23.78	12.08	200.92	160.32
8	1.093	15.67	10.99	85.71	67.37
Aver.	1.085	14.54	7.74	111.175	96.87
SD.	0.011	6.174	3.207	56.568	45.736
Critical limit	2	5	10	10 – 30	

SD:Standard deviation (statistically significant coefficients $p < .05$

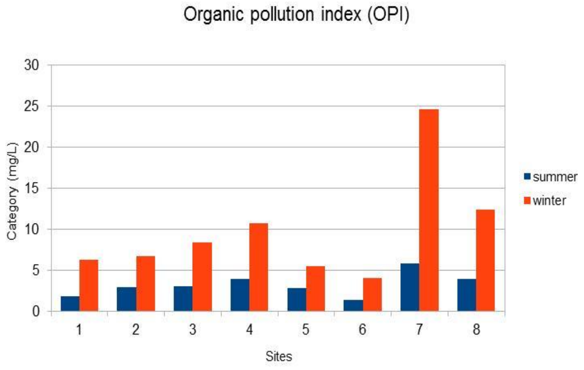

Fig. 3. Organic pollution index (OPI) at summer and winter

While, highest value OPI (24.57) was very heavily organic polluted recorded in winter at site 7. El-Qalyubia drain was also, affected by liquid wastes due to near from urban area with human activities in addition to being affected by agricultural fertilizers. Aquatic plants and phytoplankton, which take up nutrients and fix nitrogen from the atmosphere and floating chemical fertilizers, are scarce in these locations. OPI values rise as a result of the decrease in nutrient concentrations brought on by phytoplankton and aquatic plants' absorption of those nutrients, especially during the winter. The comparatively elevated levels of NH_4^+ and NO_3^- found in all seven drain locations are particularly linked to this pollution. The addition of N-fertilizers may be the reason for his. Low aeration, which results from microbes using dissolved oxygen to break down organic matter, explains the high NH_4^+ level. Based on measurements conducted at all locations throughout the winter, the OPI shows that pollution is associated with rather high levels of BOD and COD. Reeducation aeration, which occurs when organic waste breaks down and microbes utilize dissolved oxygen, explains this. Similar results were reported by Muloiwa *et al.,* (2023), who discovered that COD and ammonia removal was 157 and 15.9 mgL^{-1} at 35°C and 99 and 5.5 mgL^{-1} at 15°C, respectively.

2. Total hydrocarbons and phenol:

The findings depicted in Fig. 4 indicate that the levels of total hydrocarbons and phenol at all sites exceeded the allowable limits set by the EPA in 1986. The average concentrations of hydrocarbons and phenol in the water samples collected for this study were 3.58 and 0.86 mgL^{-1} during the summer, and 0.98 and 4.50 mgL^{-1} during the winter. The highest increases in hydrocarbon and phenol levels occurred during the summer, reaching 7.38 and 2.40 mgL^{-1}, respectively, in the winter. The nearby sampling sites exhibited similar trends, likely due to both direct and indirect sources of pollution. These sources include leakage from urban and small industrial sewer systems, as well as waterways in the study area that discharge wastewater directly into primary open drains.

Pathogenic indicators and biological parameter

Important guideline of biological criteria considers that total coliform, fecal coliform bacteria, *Salmonella* and *Shigella spp.* are arguing. Human intestinal considered the main source of FC. Therefore, coexist FC in water considered an indicator for water pollution with human wastes; meanwhile *salmonella* and *shigella spp.* are pathogenic bacteria (Wen *et al.,* 2024). The results in Table 6 showed that the numbers of total coliform bacteria ranged from 6 × 102 to 43× 102 cfu/ml in water samples taken from all sites. The results also showed that the numbers of total coliform bacteria during the winter season were less than their numbers of summer season. These values are higher than the permissible limits according to (WHO, 2006). This is due to low temperature which considered as an obstacle to increase microbial activity besides, low organic wastes in water during winter season, (Margesin and Schinner 1999). On the other hand, the study showed that the number of Fecal coliform bacteria ranged between 2× 102 to 17× 102 cfu/ml in all sites. The results also showed that the number of Fecal coliform bacteria in the summer season was higher than their number in the winter season. These numbers of Fecal coliform bacteria during the winter and summer seasons were higher than the allowable limit according to WHO, (2006). *Salmonella* and *Shigella* are considered pathogens, so there must be no colony of them in the irrigation water, because their presence causes human diseases (Wen *et al.,* 2024). The results in Table 6 showed the presence of *Salmonella* and *Shigella* in the water of all sites during the winter and summer seasons, and therefore all sites are not suitable for irrigation. Finding of *Salmonella* and *Shigella* is due to some people's bad behavior, such as, throwing dead animals in the drain and trench sludge, particularly in rural areas (Wen *et al.,* 2024).

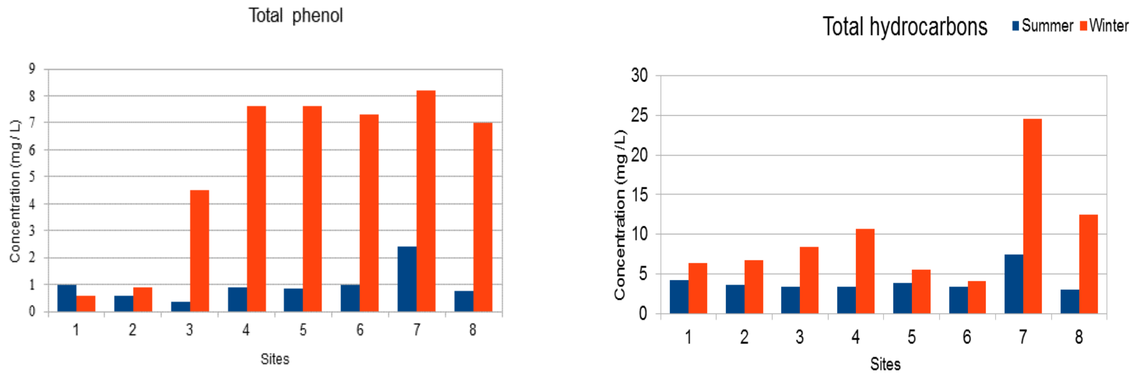

Fig. 4. Concentration of total hydrocarbons and phenol of the investigated water samples.

Table 6. Pathogenic indicators and biological parameter of water samples of El-Qalyubia main drain.

Site No.	Summer			Winter		
	cfu ml^{-1}			cfu ml^{-1}		
	Total coliforms × 10^{2}	Fecal coliforms × 10^{2}	*Salmonella & Shigella* × 10^{2}	Total coliforms × 10^{2}	Fecal coliforms × 10^{2}	*Salmonella & Shigella* × 10^{2}
1	28	14	3	26	3	1
2	43	17	7	21	10	6
3	28	9	2	22	4	1
4	34	12	5	29	2	1
5	26	8	2	13	7	1
6	28	10	3	11	6	1
7	26	9	3	21	2	1
8	24	8	2	6	3	1
Aver.	2963	1088	338	1863	463	163
Guideline*	10 – 1000	≥10	nd	10 – 1000	≥10	nd

cfu: Colony forming unit; nd: not detected *WHO (2006)

Sediment quality

Chemical indicators:

Monitoring the concentration of heavy metals in sediment gives vital information regarding their sources, distribution and degree of pollution. Table 7 showed the results of contamination factor for winter and summer season. In summer season, Cd and Cr had a CF values to be < 1 signifying the low contamination status of the sediment. The CF values for Zn, Cu and Ni were 1 < CF < 3 indicating a moderate contamination.

Table 7. Contamination factor (Cf) contents in El-Qalyubia main drain sediment sites

Site No	Fe	Mn	Zn	CU	Cd	Co	Pb	Ni	Cr
					summer				
					mgKg^{-1}				
1	4.49	10.05	1.11	1.60	0.11	1.02	3.72	1.77	0.03
2	4.37	8.39	1.06	2.00	0.04	0.62	1.60	0.04	0.03
3	3.82	7.51	1.11	1.80	0.09	0.84	55.48	1.02	0.02
4	4.56	9.56	1.05	2.20	0.22	0.83	20.06	0.19	0.02
5	4.69	9.87	1.25	2.00	0.07	1.00	33.92	0.59	0.03
6	4.95	9.65	1.13	2.00	0.09	1.03	156.30	0.86	0.04
7	5.14	10.70	1.19	1.60	0.09	1.02	127.90	0.76	0.03
8	5.01	11.17	1.06	1.80	0.06	1.53	2.05	0.26	0.02
Aver.	4.63	9.612	1.12	1.88	0.09	0.99	50.13	0.69	0.03
SD.	0.424	1.182	0.070	0.212	0.054	0.262	60.162	0.558	0.007
				winter					
1	28.504	84.000	17.920	742.400	0.120	2.688	5.626	0.540	0.168
2	46.356	61.453	112.587	358.400	0.424	2.556	5.708	2.008	0.038
3	4.582	41.273	106.720	354.400	0.276	3.396	7.678	4.226	0.042
4	4.676	51.213	57.267	324.200	2.012	1.628	2.780	1.088	0.032
5	22.172	114.733	112.533	833.600	0.184	3.212	2.550	0.994	0.022
6	49.708	86.800	113.333	510.800	0.136	2.496	4.868	1.244	0.003
7	44.752	60.160	57.267	608.400	0.416	2.876	1.680	4.404	0.041

Site No	summer								
	Fe	**Mn**	**Zn**	**CU**	**Cd**	**Co**	**Pb**	**Ni**	**Cr**
8	0.036	0.029	24.393	200.760	0.012	0.016	0.052	0.004	0.001
Aver.	25.098	62.458	75.253	491.620	0.448	2.359	3.868	1.814	0.043
SD.	20.459	34.368	40.961	221.376	0.648	1.086	2.515	1.647	0.053

SD: Standard deviation (statistically significant coefficients p < .05

The CF values for Fe, Mn and Pb were CF > 3 indicating a high contamination in the eight sites. In winter season, Cr had a CF values to be < 1 signifying the low contamination status of the sediment, while CF for Fe, Mn, Zn, Cu, Co, Ni and Cd were > 3 indicating a high contamination in the eight sites. This shows that pollution with sediment is most likely high affected by the season. The high the CF values of Fe, Mn, Zn, Cu, Co, Ni and Cd in all sampling sites are due to the accumulation of the trace element in sediment which depends on the increased man-made activates in the winter the heavy rainfall leading to high fluvial inputs. The transport of the industrial waste alongside with the soil materials by the erosion activities into the drain should increase pollution of the sediment during winter season. These findings were agreed with, (Gulten, 2022). The higher sediment concentration of Cr, Cu, Ni, Zn, and Li and As during the rainy period can be explained by the river bank runoff and surface runoff from agricultural and urban areas. As it is known, metals accumulate in sediment due to precipitation and sorption processes and return to the drain with dissolution and desorption processes and negatively affect the water quality, (Wang *et al.,* 2020). Significant levels of As, Cd, Hg, Ni, Pb, and Zn are present in fertilizers used in agricultural operations. Furthermore, the most significant non-point sources of trace metals are pesticides and fertilizers used in agricultural areas.

Organic indicators (total hydrocarbons and phenol):

The results shown in Table 8, Indicated that the average levels of hydrocarbon and phenol in the sediment samples were 25.83 and 271.73 mgL^{-1} during the summer and 8.28 and 28.23 mgL^{-1} during the winter, respectively. The highest increase in hydrocarbons and phenol was recorded during the summer season, reaching 3.12 and 21.83 times in the winter season. This is due to sewage leakage from urban units and small industrial units in the study area to drain. It is said that the increase in hydrocarbon and phenol levels during the summer is primarily attributed to the heightened human activity and industrial operations, resulting in a significant discharge of these toxic pollutants into the water bodies. This discharge is caused by sewage leakage, which originates from both urban and small industrial units surrounding the study area. As the temperature rises in summer, the rate of decomposition of organic matter and the subsequent release of hydrocarbons and phenol from the sediments increase drastically.

Table 8. Organic pollutants concentration in Sediment samples of the study area.

Site No.	Total hydrocarbons		Total phenol	
	mgkg^{-1}			
	summer	winter	summer	winter
1	37.55	8.23	261.60	81.83
2	25.22	8.43	285.00	17.4
3	25.51	8.03	293.50	25.13
4	25.61	7.55	295.60	6.09
5	21.24	7.36	265.90	8.38
6	16.68	7.65	255.30	10.95
7	27.84	7.94	261.60	68.94
8	26.97	11.04	255.30	7.09
Aver.	25.83	8.28	271.73	28.23
SD.	5.952	1.171	16.898	29.969
Critical limit*	<0.0001		<0.5	

SD:Standard deviation (statistically significant coefficients (p < .05); EAP (1989)

Consequently, the sediment samples taken during the summer season exhibited significantly higher concentrations of hydrocarbon (25.83 mgL^{-1}) and phenol (271.73 mgL^{-1}) compared to the winter season, where the levels declined to 8.28 mgL^{-1} and 28.23 mgL^{-1}, respectively. This stark difference in concentrations indicates the direct impact of seasonality on the accumulation and release of hydrocarbons and phenol in the sediments. Thus, it is evident that the summer season poses a greater risk in terms of pollution due to the substantial increase recorded, making it crucial to implement effective measures to combat these hazardous substances.

Pathogenic indicators:

Table 9 shows the total fecal coliform bacteria, as well as *Salmonella* and *Shigella* from the investigated sediment. The number of total coliform bacteria (65 × 10^2 and 90 × 10^2 cfu gm^{-1}) were higher than fecal coliform bacteria (11 × 10^2 and 40 × 10^2 cfu gm^{-1}) and also, higher than *Salmonella & Shigella* (100 and 22 × 10^2 cfu gm^{-1}). The results also revealed that the number of pathogenic bacteria in the sediment was higher in the winter than in the summer in all sites. The results also, revealed that the number of pathogenic bacteria in the sediment was higher than in water samples taken from the same sites. The results obtained are consistent with what was reported by, (Abd-Elfattah *et al.,* 2021).

Table 9. Pathogenic indicators of sediment samples of El Qalubiya main drain.

Sample No.	Summer Season cfu gm^{-1}			Winter Season cfu gm^{-1}		
	Total coliforms × 10^2	Fecal coliforms × 10^2	*Salmonella & Shigella* × 10^2	Total coliforms × 10^2	Fecal coliforms × 10^2	*Salmonella & Shigella* × 10^2
1	42	13	4	70	14	3
2	65	23	6	90	27	1
3	35	12	3	62	25	22
4	42	17	4	52	29	3
5	36	12	4	53	15	2
6	40	14	5	77	40	3
7	43	14	4	61	30	8
8	34	11	3	65	23	3
Average	4213	1450	413	6625	2538	563

CONCLUSIONS

The study conducted sheds light on the remarkable levels of pollution detected in the El Qalyubia main drain, surpassing the permissible limits across various crucial parameters. These findings strongly emphasize the urgency of implementing essential measures to address and rectify the wastewater pollution issue prior to its discharge. This action is imperative not only to safeguard environmental well-being but also to guarantee the utmost safety and efficacy of irrigation practices. Therefore, immediate steps must be taken to tackle this concern effectively and mitigate any potential risks posed to the ecological balance and public health.

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تقييم المياه والرواسب لمصرف القليوبية الرئيسي، شرق الدلتا، مصر

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الملخص

يعد تلوث المياه من أهم أسباب لمراقبة وتقييم جودة المياه. وقد تتأثر الجودة الكيميائية والبيولوجية لمياه العادمة بالأنشطة البشرية مثل الأنشطة الصناعية والحضرية والزراعية. ويعد الصرف الرئيسي بالقليوبية مياهًا ملوثة ناتجة عن تدفق مياه الري والصرف الصحي المنزلي والصناعي. وكان الغرض من هذه الدراسة تحديد مؤشر جودة المياه والرواسب خلال صيف 2022 وشتاء 2023. وتم جمع عينات المياه والرواسب من ثمانية مواقع على طول المصرف وتحليلها لمعايير كيميائية مختلفة. بالإضافة إلى ذلك، تم تحديد العناصر النادرة والمعايير الميكروبية. تمت مقارنة النتائج بالحدود المسموح بها لمياه الرى. وقد اختلفت النتائج التي تم الحصول عليها من موقع إلى آخر وذلك بسبب طبيعة النفايات الناتجة عن الأنشطة المختلفة التي تجري حول مصرف القليوبية الرئيسي. وقد أظهرت النتائج أن بعض العوامل الكيميائية والبيولوجية مثل المواد الصلبة الكلية والمواد الصلبة العالقة الكلية ونسبة الصوديوم الذائبة ودليل التلوث العضوي ودليل التلوث الشامل وعامل التلوث والهيدروكربونات والفينولات كانت لها قيم أعلى من الحد الموصى به لمياه الصرف الصحي، في حين أن بعض العوامل الأخرى حيث وجد أن المواد الصلبة الذائبة الكلية ودرجة الحموضة والتوصيل الكهربائي والكلوريد والمغنيسيوم (الصلابة الكلية والمؤشرات المسببة للأمراض) تقع ضمن الحد المسموح بها. واستناداً إلى مؤشر جودة المياه والرواسب تبين أن نوعية المياه والرواسب تتأثر بالأنشطة الصناعية والعمرانية والزراعية، لذا فإن معالجة هذه المياه العادمة بشكل رئيسي من الملوثات أمر ضروري لضمان سلامة وصحة البيئة.