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Relationship Between Plankton Communities and Heavy Metals in the Rosetta Branch, the River Nile, Egypt

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ABSTRACT

The River Nile is the essence of life in Egypt; the last decades have witnessed changes in its water quality due to several factors associated with anthropogenic activities. Therefore, the aim of this study was to evaluate the ecological status of the River Nile at the Rosetta branch by addressing the relationship of plankton densities and heavy metals. 99 species of phytoplankton were recorded belonging to 6 major groups, with the dominance of diatoms. While, 39 species of zooplankton were recorded belonging to 4 major groups, with the dominance of Rotifera. The concentration of heavy metals in the surface layer of the study areas varies with the season and site with the prevalence of Al, followed by Fe, Mn, Zn, Ni, Co, and Cd. Pearson's correlation and redundancy analysis showed that the concentrations of these metals are correlated with the abundance of selected dominant phytoplankton and zooplankton species. In addition, Van Dobben circles analysis elucidated that heavy metals are significantly contributed to the species richness and distribution. Thus, it is recommended to establish sewage water treatment plants in the Rosetta branch before draining into the Nile.

INTRODUCTION

The Nile River is the lifeline supplying water to millions of people. It extends to the Mediterranean Sea via two main branches, Rosetta and Damietta, which are flowing through the Nile delta wetland **(Badr *et al.*, 2006)**. The Nile water is essential for the Egyptians' life, yet the quality of the river's water has declined in recent decades due to several human-caused problems. Rosetta branch, located on the western side of the River Nile, is subject to a wide range of pollutants. Pollutants primarily come from the El-Rahawy drain and the industrial operations in Kafr El-Zayat city **(Salaah *et al.*, 2018)**.

The Nile River is the primary source providing Egypt with guaranteed water. **(Al Sherif, 2009)**. As a result of its rapidly expanding population, Egypt is among the top ten countries most likely to experience water scarcity by 2025 **(Engelman & LeRoy, 1993)**. The main pollution sources in the River Nile are agricultural and domestic wastes.

The Rosetta branch is roughly 220km long, 180m wide, and 1.5 to 16.0m deep. It flows downstream the Delta barrage to the northwest, ending with Edfina barrage that floods water into the Mediterranean Sea. Unfortunately, it receives polluted water from industrial, agricultural, and urban sewage sources, harming the ecological freshwater state of this area (**Elewa *et al*., 2009)**.

Rosetta branch's water pollution is originated from two sources: the agricultural drainage water from five major drains (El-Rahawy, Sabal, El-Tahrir, Zaweit El-Bahr and Tala), directly flowing into this branch and the industrial wastewater that flows via the branch. These drains collect a wide variety of contaminants, including animal and human waste, sediments, inorganic salts, crop residues, minerals, chemical fertilizers and pesticides **(Donia, 2005)**. The second source of pollution is the industrial wastewater outfalls produced by mega-companies in Kafr El-Zayat city; these industrial outfalls are Salt and Soda, El-Mobidat, and El-Malyia companies, which are directly discharged at the east bank of the branch **(Usali & Ismail, 2010)**

It is crucial to evaluate the impacts of heavy metals on biological species and the relationships between those effects to protect the aquatic ecosystem. Therefore, heavy metals can enter aquatic species and then bio-accumulate and bio-magnify as they go up the food chain, presenting serious dangers **(Dhanakumar *et al*., 2015)**.

In addition to temperature, rainfall, pH, salinity, and dissolved oxygen, other parameters affect the aquatic environment, such as total suspended and dissolved solids, total alkalinity, and heavy metal pollutants that limit the survival of aquatic organisms (flora and fauna). Poor water quality may be caused by reduced water flow, municipal effluents and industrial discharges **(Chitmanat & Traichaiyaporn, 2010)**.

Environmental degradation caused by water pollution has a high cost since it negatively affects people's health and quality of life and makes water scarcity issues even more pressing. The deterioration of water quality is just one among many adverse effects of water pollution, which also endangers human health, aquatic ecosystems, economic development and social prosperity **(Zyadah, 1996)**. Due to its closed water system, Egypt is more susceptible to quality deterioration in a northward direction toward the Nile Delta **(Abdel-Dayem, 2011)**.

An overabundance of nutrients and contaminants encourages the primary productivity and biomass growth of phytoplankton **(Urrutxurtu *et al*., 2003)**. The biomass of phytoplankton is used as a bio-monitoring index; however, its density directly affects the productivity of aquatic ecosystems (**Benarjee & Narasimha, 2013**). For example, epiphytic microalgae determine the trophic status of aquatic ecosystems **(Cook, 2007)**. It is considered as a good bioindicator due to its fast reproduction rates and high sensitive responses to chemical variations and eutrophication **(Larson & Passy, 2012)**. Additionally, it is considered as a source of food for invertebrates and fishes at the coastal zones **(Abe *et al*., 2007)**.

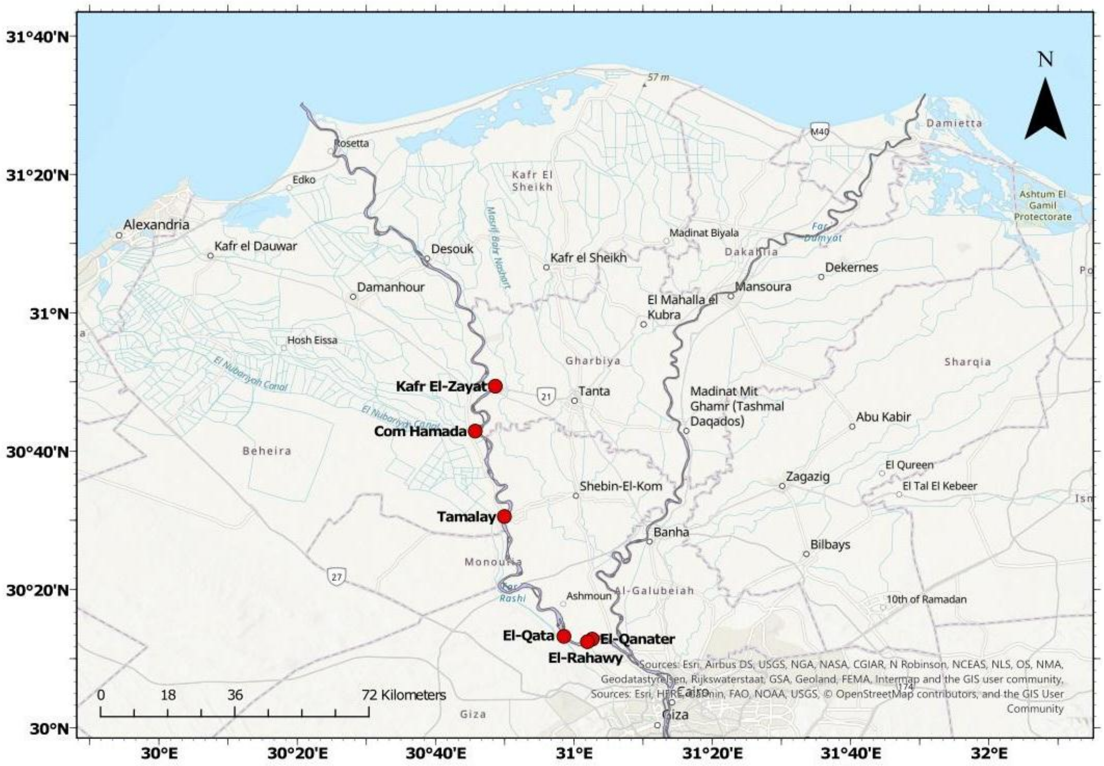

Fig. 1. The map of the selected sites at the Rosetta branch (The Nile River)

The composition of plankton communities is frequently employed as a bioindicator of ecological change in aquatic environments **(Lemley *et al.*, 2016)**. Since they quickly adapt to any changing conditions in their habitat, plankton populations are considered good natural bioindicators **(Amengual-Morro *et al.*, 2012)**. Phytoplankton populations, in particular, reflect the drastic shifts in climate occuring in aquatic ecosystems **(Leterme *et al.*, 2005)**. On the other hand, zooplankton populations are regarded as perfect bioindicators for estuary conditions since they may persist in the water body of appropriate water quality **(Albaina *et al.*, 2009)**. Given that coastal lagoons are among the world's most productive and dynamic environments, understanding the impact of environmental variability on ecological changes in these areas is crucial **(Gönenç & Wolflin, 2005)**.

This study aimed to evaluate the ecological status of the River Nile at Rosetta branch by addressing the relationship of plankton communities in the presence of heavy metals.

MATERIALS AND METHODS

1. Area of investigation

Six sites including El-Qanater Al Khairiya, El-Rahawy, El-Qata, Tamalay, Com Hamada and Kafr EL Zayat, were chosen in Nile River to cover the studied area during the period from August 2019 to April 2020, with successive seasonal collection (Table 1 & Fig. 1). Water samples were collected to investigate water quality, phytoplankton and zooplankton.

Phytoplankton and zooplankton species composition, abundance of groups, and the impact of pollution on their availability were studied.

Table 1. Sampling sites of River Nile

Site	Location	Latitude	Longitude
1	El-Qanater	30° 12′ 48.79″ N	31° 2′ 39.26″ E
2	El-Rahawy	30° 12′ 26.53″ N	31° 1′ 57.84″ E
3	El-Qata	30° 13′ 12.93″ N	30° 58′ 33.77″ E
4	Tamalay	30° 30′ 32.32″ N	30° 49′ 57.29″ E
5	Com Hamada	30° 42′ 52.91″ N	30° 45′ 44.28″ E
6	Kafr El-Zayat	30° 49′ 22.64″ N	30° 48′ 38.93″ E

2. Plankton investigation

The phytoplankton counts were measured according to **APHA (2017)**; triplicate samples (2 or 5µl) were gathered and examined under inverted microscope ZEISS IM 4738, with magnification power 100x. The results of phytoplankton data were presented as the number of cells per liter (cell/l). Phytoplankton identification was performed according to **Munshi *et al*. (2010)** and **Bellinger and Sigee (2015)**. The currently accepted nomenclature was given according to **Guiry and Guiry (2022)**.

Zooplankton samples were examined using an optic research microscope. Three sub-samples (one ml each) of the homogenized plankton samples were transferred for the quantity and differentiation of microorganisms. The organisms were counted, identified and described according to **Dang *et al.* (2015)** and calculated according to **APHA (2017)**.

3. Analytical methods for heavy metals

The analysis of heavy metals was carried out according to **APHA (2012**), using an inductively coupled plasma spectroscopy (ICP-OES) model Agilent 5100 Synchronous Vertical Dual View (SVDV).

Quality Control. Precision of metal ion measurements were determined by analyzing (triplicate) the metal ion concentrations in samples; for each series of measurements, a constructed absorption calibration curve composed of a blank and five standards was considered. The accuracy of the measurements was confirmed using external standard reference material for the elements in water and quality control samples from the National Institute Standards and Technology (NIST).

4. Statistical analysis of the collected data

Pearson's correlation. It was performed to assess the relationship between the phytoplankton, zooplankton and heavy metals concentrations.

Redundancy analysis (RDA). It was performed using the covariance method to determine the relative significance of heavy metals in explaining the variability of the tested samples. The dataset was log transformed (log (n + 1)) and centered on species, as this was obligatory for the constrained linear methods.

Consequently, the relationships between heavy metals and dominant phytoplankton and zooplankton density were analyzed by RDA. The data were statistically processed in Canoco 5.0 software **(Ter Braak & Smilauer, 2002)**.

To explore significant positive and negative relationships between dominant plankton and specified heavy metals of tested area, t-value biplots (with van Dobben circles) were generated, with an approximate t-values of the regression coefficients of a weighted multiple regression. The t-value biplots signify the plankton data which, to a large extent, reacted to the tested factor **(Ter Braak & Smilauer, 2002)**.

5. Diversity indices

They were carried out on data at the selected sites by using premier program version 5.

5.1 *Species richness index*

One of the major components of species diversity is ‘Species richness’ or Margalef’s diversity index (d) and is expressed by simple ratio between total number of species (n) and total number of individuals (N); where, **d = n-1 / log N**.

The richness commonly varies between 1 and 5, and the larger the index the more healthy the waterbody, and when it tends towards1, pollution is thought to increase **(Margalef, 1958; Patra *et al.*, 2011)**.

5.2 Evenness (J)

Evenness (J) was calculated according to the Shannon Index **(Shannon & Weaver, 1963)**, using the formula: **J = H’max / S**.

Where, "S" is the total number of species of each sample, and "H’max" is the number of maximal theoric diversity. More than 0.5 is considered even.

5.3 *Shannon-Wiener index (H')*

The Shannon- Wiener index of species diversity was applied according to **Weber (1973)**. Index was used to express the extent of diversity of species among the different sites and seasons according to the following equation:

$$H' = - \Sigma (ni/N) \log2 (ni /N)$$

Where, ni = represents the number of individuals of I species, and N = represents the total number of individuals.

Diversity index between 0 and 3 means a medium pollution, and a diversity index > 3 means clean water **(Wilhm, 1972)**.

5.4 Simpson

The index of dominance **(Simpson, 1949)** is the sum total of squares of the proportion of the species in the community and is expressed as follows: $c = \Sigma (ni / N) 2$

Where, c = Index of dominance; ni = Importance value for each species, and N = Total importance value. The value of ‘c’ varies between 0 and 1. Higher diversity values reflect diversified resources in the habitat available for components of the community. Decreased values indicate increase by an average species resulting in the lowering of the number of coexisting species in the community.

RESULTS AND DISCUSSION

1. Plankton investigation

1.1 Phytoplankton community structure

There were a total of 99 different species of phytoplankton found in the areas studied and throughout the investigation. They belong to 6 different phyla:

Bacillariophyta (26 sp.), Chlorophyta (38 sp.), Cyanobacteria (19 sp.), Miozoa (Dinoflagellates) (2 sp.), Euglenozoa (7 sp.), and Charophyta (7 sp.).

The maximum seasonal average in phytoplankton densities is shown in summer, which amounted to about 2034.2×10^4 unit/l, forming about 31.1% of the annual average of the standing crop. In comparison, the minimum phytoplankton average was recorded through autumn, which amounted to 1260.8×10^4 unit/l, constituting about 19.3% of the annual average of the standing crop. The highest annual phytoplankton density was observed in site (R4) (Com Hamada), and the lowest one was recorded in site (Q) (El-Qanater) (Table 2).

The annual average of the phylum composition ratio cleared that Bacillariophyta was the most predominant one, forming about 55.6% from the total phytoplankton density, followed by Cyanobacteria, representing about 23.4%, and Chlorophyta which ranked the third position, constituting about 18.3%. Charophyta, Euglenophyta, and Miozoa are recorded with lower ratios (1.5, 1.1, and 0.1%, respectively) (Figure 2 & 3). **Konsowa, 2001 and Tahoun et al., 2021** recorded that Bacillariophyta were the dominant phylum in Rosetta branch.

Shaaban et al., 2011 showed that the dominant group of phytoplankton in Kafr El-Zayat city from Rosetta branch was Chlorophyta phylum during period from summer 2006 to summer 2007, while during period from autumn 2007 to winter 2007 was dominated with Bacillariophyta phylum**.**

The highest **Richness** index values (9.84) was recorded in Com Hamada site (R4) then Tamalay and Kafr El-Zayat sites (R3 and R5) (9.59) but the lowest one (5.93) appeared in El-Rahawy site (R1); this indicated that the water body was healthy. At the same time, the **Evenness** index values were even because all values of evenness were more than 0.5. Also, all values of **Shannon** diversity index were more than 3; this indicated that water body was clean. On the other hand, **Simpson** index values were near 1; this referred to diversity increasing in the studied sites. Generally, the previous results indicated that the diversity of phytoplankton in the studied sites was increased (Table 4).

Table 2. Seasonal variations of phytoplankton densities (No. of units ×104/l) in the studied area during 2019-2020

Sites	Seasons				Annual average
	Summer	Autumn	Winter	Spring	
Q	360	960	2130	1440	1222.5
R1	1800	2850	1535	560	1686.25
R2	1250	845	2410	1085	1397.5
R3	1500	1125	1870	1555	1512.5
R4	4605	875	2405	1295	2295
R5	2690	910	1470	1695	1691.25
Seasonal average	2034.2	1260.8	1970	1271.7	

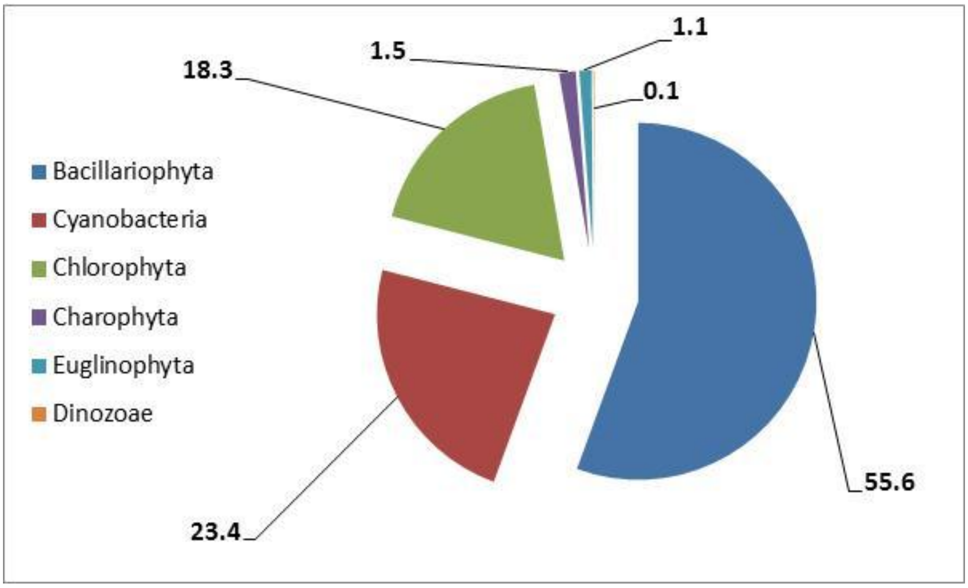

Fig. 2. Annual average of Phytoplankton phyla composition ratio in the studied area during 2019-2020

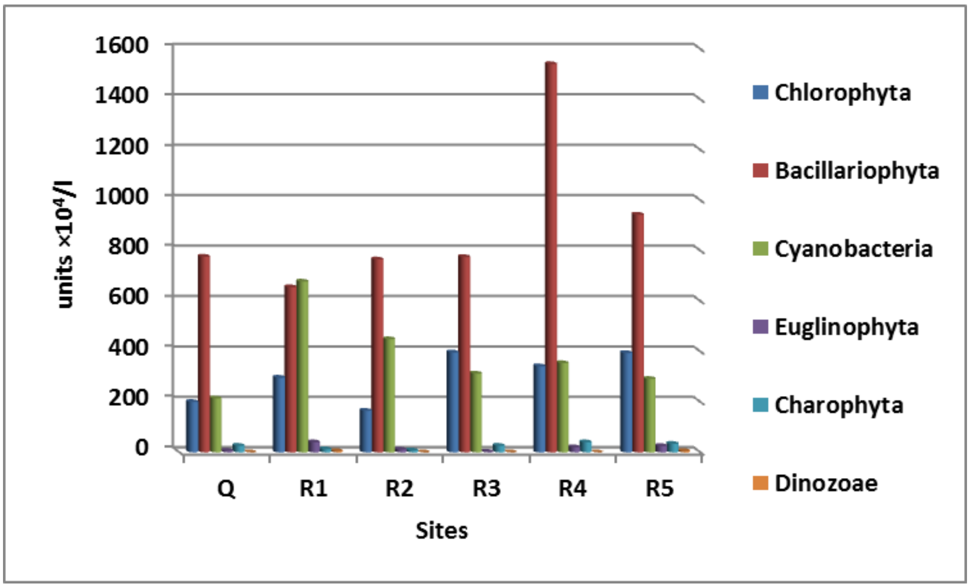

Fig. 3. Annual average of Phytoplankton groups composition in the studied area during 2019-2020

1.2 Zooplankton community structure

39 species of zooplankton were recorded in the studied areas; along the investigated period, belonging to 4 major groups, phyla: Rotifera (27 sp.); Protozoa (2 sp.); Arthropoda (9 sp.); and Nematoda (1 sp.).

Maximum seasonal average in zooplankton densities is showed in spring; which amounted about 3089.83 Org./l, forming about 32.1% of the annual average of the standing crop. In comparison, the minimum zooplankton average was recorded through summer, which amounted to 1176 Org./l, constituting about 12.22% of the annual average of the standing crop. The highest annual zooplankton density was recorded in Tamalay site (R3), and the lowest one was recorded in El-Rahawy site (R1) (Table 3).

The annual average of the group composition ratio cleared that Rotifera was the most predominant one, forming about 70.64% from the total zooplankton density, followed by Protozoa, representing about 23.55%. Arthropoda and Nematoda are recorded with lower ratios (4.01 and 1.8%, respectively) (Figure 4 & 5).

Previous research on Rosetta branch revealed that, Rotifera dominated the other zooplanktonic groups (**Saad et al., 2013; Hegab and Khalifa, 2021; Tahoun et al., 2021**)

The highest **Richness** index values (2.73) was recorded in Kafr El-Zayat site (R5) (2.56) but the lowest one (2.17) appeared in El-Rahawy site (R1). That indicated to the body water was moderate polluted. At the same time, the **Evenness** index values were even because all values of **Evenness** were more than 0.5. Also, the highest **Shannon** diversity index values (2.62) was recorded in Kafr El-Zayat site (R5) while the lowest one (1.61) appeared in El-Qata site (R3), and these values indicated to moderate pollution. On the other hand, **Simpson** index values were tend to 1 except site R3 (0.65), and that indicated to increasing the diversity of zooplankton species in the studied sites. Generally, the previous results indicated to the diversity of zooplankton in the studied sites were moderated (Table 4).

Table 3. Seasonal variations of Zooplankton densities (Org/l) in the studied area during 2019-2020

Zooplankton species	Seasons				Annual average
	Summer	Autumn	Winter	Spring	
Q	599	3796	4463	1332	2547.5
R1	1197	200	866	1398	915.25
R2	598	344	1499	1864	1076.25
R3	232	3431	4496	5284	3360.75
R4	1066	4530	2864	2965	2856.25
R5	3364	3265	2399	5696	3681
Seasonal average	1176	2594.33	2764.5	3089.83	

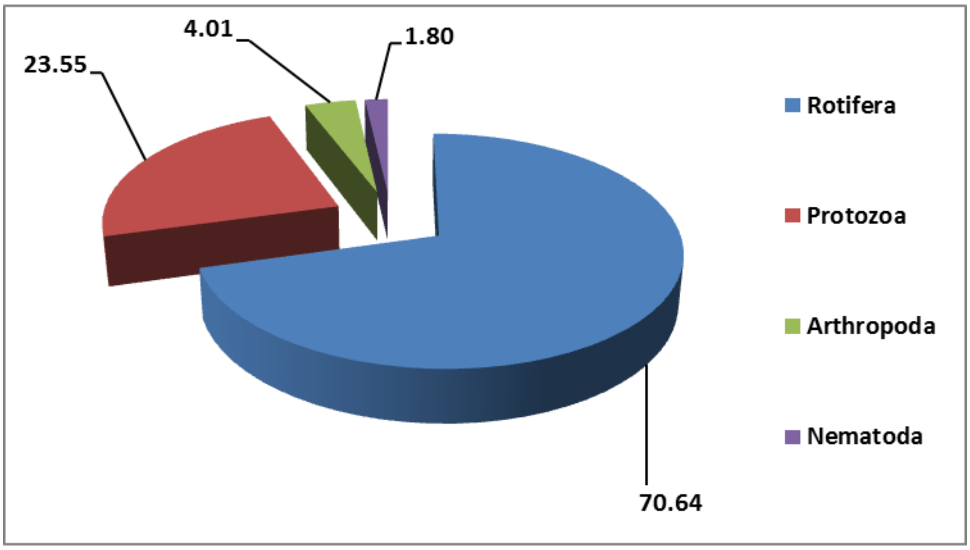

Fig. 4. Annual average of zooplankton groups composition ratio in the studied area during 2019-2020

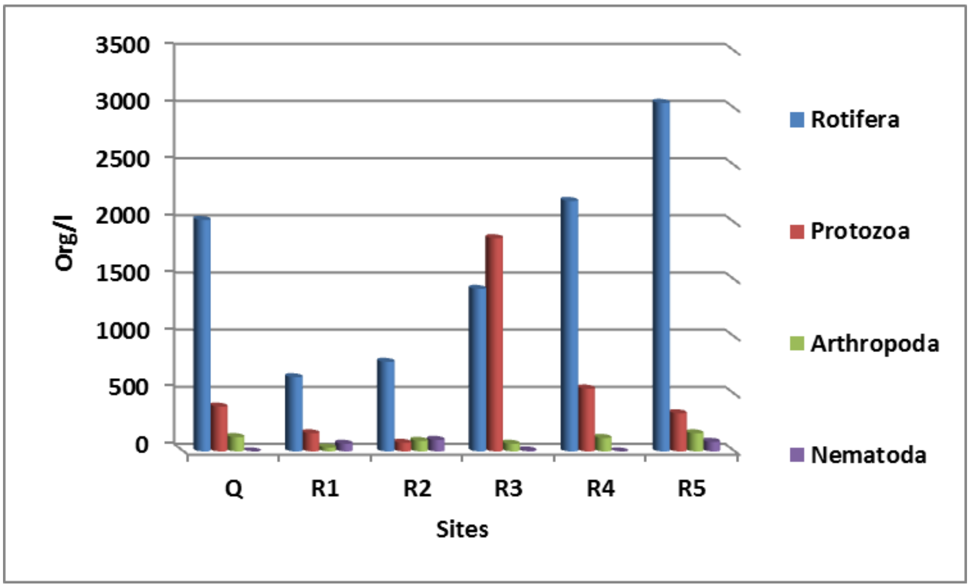

Fig. 5. Annual average of zooplankton groups composition in the studied area during 2019-2020

Table 4. Diversity indices of Plankton in the studied area during 2019-2020

Sites	Species Richness		Evenness		Shannon		Simpson	
	Phyto.	Zoo.	Phyto.	Zoo.	Phyto.	Zoo.	Phyto.	Zoo.
Q	8.6	2.17	0.77	0.73	3.16	2.12	0.92	0.84
R1	5.93	2.5	0.82	0.69	3.12	2.01	0.94	0.8
R2	8.3	2.56	0.78	0.8	3.22	2.39	0.94	0.88
R3	9.59	2.22	0.81	0.55	3.45	1.61	0.94	0.65
R4	9.84	2.39	0.73	0.76	3.19	2.29	0.92	0.87
R5	9.59	2.73	0.77	0.85	3.28	2.62	0.92	0.9

2. Heavy metals

The concentration of heavy metals in the surface layer of study areas varies with the season and site. Annually, the concentrations of the elements come as follows; Al > Fe> Mn> Zn> Ni > Co > Cd as shown in Table 5. Aluminum element showed the highest seasonal average during autumn season (1.638 mg/l), while cadmium showed the lowest seasonal average during summer (0.001 mg/l).The highest spatial presence was for aluminum metal during the autumn season in El-Rahawy site (R1) (4.713mg/l).

Konsowa, 2001 confirmed that the abundances of the various metals in the Rosetta Branch can be arranged in descending order as follows: Fe > Mn > Ni > Pb > Co > Zn > Cd > Cu > Hg.

Redundancy Analysis (RDA) was used in this study to postulate the potential relation between heavy metals concentration and abundances of dominant plankton. Figure 6 shows the RDA of plankton abundance with metal concentrations. There were four axes with eigenvalues of 0.090, 0.066, 0.034, and 0.025, respectively. They had contributed to 23.8% of explanatory variables. The RDA demonstrated that, the concentrations of Al, Fe, Mn, Zn, and Co correlated with abundance of some dominant phytoplankton species (*Achnanthidium minutissimum, Cyclotella meneghiniana*, *Cylindrotheca closterium*, *Aphanocapsa elachista* and *Chlorella vulgaris*; the concentrations of Cd, and Ni correlated with the abundance of some dominant phytoplankton species (*Aulacoseira granulate*, *Diatoma elongate, Pantocsekiella ocellata* and *Ulnaria ulna);* and dominant zooplankton species (*Vorticella* sp., *Philodina* sp., *Brachionus calyciflorus*, *Polyarthra vulgaris, Keratella cochlearis*, *Trichocerca elongate*, and *Brachionus quadridentatus*).

T-value biplot: T-value biplots along with van Dobben circles elucidated that heavy metals significantly contributed to the species richness and distribution (Figure 7). Species in all zones showed strong positive response toward studied heavy metals.

These results are compatible with Pearson's correlation analysis, which showed positive correlation between *Achnanthidium minutissimum* and *Cyclotella meneghiniana* with Co metal (0.45 and 0.5) respectively; *Aphanocapsa elachista* and Fe, Mn, Al, and Zn metals (0.52, 0.58, 0.71 and 0.61) respectively; *Chlorella vulgaris* and Mn, Al, and Zn metals (0.44, 0.53 and 0.52) respectively; *Brachionus quadridentatus* with Cd metal (0.51) (Table 6).

Many authors have observed a positive correlation between plankton (phytoplankton and zooplankton) densities and metal concentrations in contaminated sites, particularly the dominant species in this study.

Several authors noted a positive relationship between plankton densities (phytoplankton and zooplankton) and metal concentrations in contaminated sites, particularly the dominant species in this study, where the positive relationship between the heavy metals such as (Cu, Fe, Mn, Zn, Cd, Ni, As and Pb) and the species of phytoplankton prevailing such as *Achnanthidium minutissimum* (**Kim et al., 2008; Morin et al., 2012; Luís et al., 2011**); *Cyclotella meneghiniana* **(El-Bestawy, 2000)**; *Aulacoseira granulate* and *Pantocsekiella ocellata* **(Hussian, et al., 2018)**; *Cylindrotheca closterium* **(Becker and Copplestone, 2019; Radić et al., 2021)**; *Aphanocapsa elachista* **(Abdel-Raouf and Ibraheem, 2001)**; *Ulnaria ulna* **(Shin et al., 2020)**; and *Chlorella* (**Mehta and Gaur, 2005**; **Dewi and Nuravivah, 2018**).

Also, the positive correlation between the heavy metals such as (Al, Cu, Cd, Ni, Hg, Cr and Pb) and the species of dominant zooplankton such as *Vorticella microstoma* (**Rehman et al., 2010**); *Brachionus calyciforus, Polyarthra vulgaris and Keratella quadrata* (**Atici et al., 2010**); *Trichocerca elongate*, and *Brachionus quadridentatus* (**García-García et al., 2012)** and *Philodina* sp. (**Ricci and Pozzoli, 1979).**

The possibility of zooplankton accumulation showed a preference for basic metals in the order Cu > Fe > Mn > Zn > Cd > Ni > Pb > Co. (**El-Metwally et al., 2022**). The rotifer was the most tolerant of the El-Rahawy drain water, which was loaded with sewage, agricultural and heavy metals (**Saad et al., 2013)**.

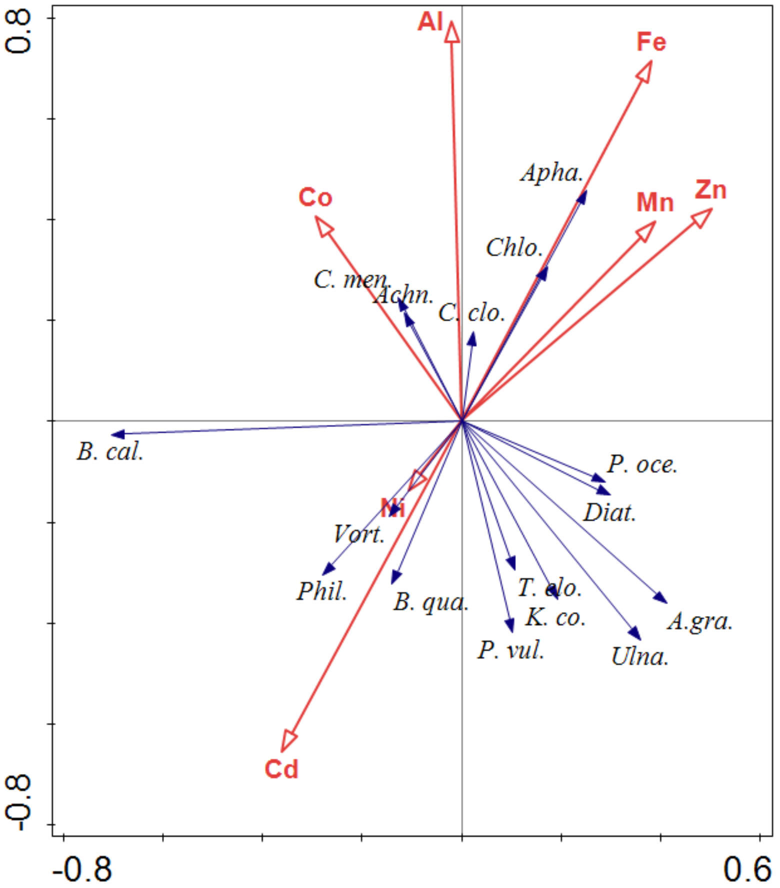

Fig. 6. Redundancy Analysis (RDA) ordination plot of heavy metals and dominant plankton abundance for Rosetta branch, River Nile, Egypt

Achn: Achnanthidium minutissimum, A. gra.:Aulacoseira granulate, C. men.: Cyclotella meneghiniana, C. clo.: Cylindrotheca closterium, Diat.: Diatoma elongate, P. oce.: Pantocsekiella ocellata,Ulna.: Ulnaria ulna, Apha.: Aphanocapsa elachista, Chlo.: Chlorella vulgaris, Vort.:Vorticella sp., *Phil.: Philodina* sp., *B. cal.: Brachionus calyciflorus, P. vul.: Polyarthra vulgaris, K. co.: Keratella cochlearis, T. elo.: Trichocerca elongate*, and *B. qua.: Brachionus quadridentatus*

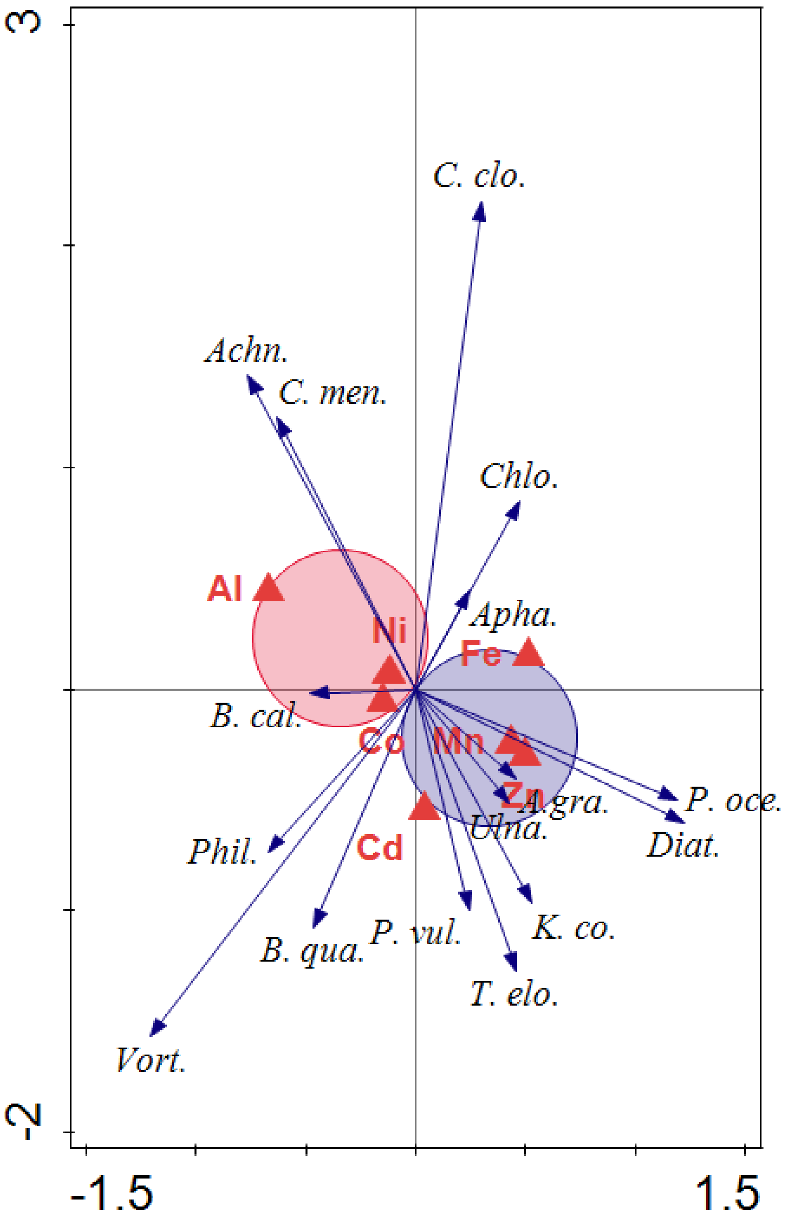

Fig. 7. A t-value biplot with van Dobben circles based on the redundancy analysis of heavy metals in surface water and dominant plankton denisties

Table 5. The concentration of heavy metals (mg/l) for surface water in the studied area during 2019-2020

Sites	Ni				Co				Fe				Mn				Al				Zn				Cd			
	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp
Q	0.013	0.016	0.014	0.016	0.001	0.001	0.001	0.002	0.572	0.765	0.491	1.014	0.035	0.097	0.077	0.161	0.842	1.356	0.755	0.403	0.045	0.109	0.081	0.034	0.001	0.001	0.001	0.001
R1	0.011	0.015	0.016	0.015	0.001	0.002	0.002	0.002	0.466	2.394	1.781	0.337	0.039	0.444	0.321	0.069	0.980	4.713	2.821	1.221	0.055	0.131	0.044	0.028	0.001	0.001	0.001	0.002
R2	0.013	0.011	0.011	0.012	0.001	0.001	0.001	0.001	2.513	0.882	0.514	0.286	0.079	0.259	0.192	0.058	2.084	1.281	0.559	1.082	0.092	0.063	0.031	0.036	0.001	0.001	0.001	0.001
R3	0.015	0.011	0.016	0.012	0.001	0.001	0.002	0.001	1.631	0.821	1.078	0.378	0.056	0.089	0.194	0.029	1.999	1.165	1.419	0.797	0.062	0.071	0.041	0.018	0.001	0.001	0.001	0.002
R4	0.011	0.012	0.017	0.029	0.001	0.001	0.001	0.001	0.727	0.453	1.037	0.371	0.033	0.027	0.184	0.044	0.591	0.597	0.391	0.798	0.076	0.014	0.029	0.072	0.001	0.002	0.002	0.002
R5	0.017	0.012	0.011	0.016	0.007	0.001	0.001	0.001	1.745	0.518	1.381	0.093	0.062	0.073	0.091	0.079	2.832	0.716	2.031	1.151	0.089	0.084	0.025	0.031	0.001	0.001	0.002	0.001

Table 6. Pearson's correlation between dominant phytoplankton, zooplankton, and heavy metals concentrations in the studied area during 2019-2020

	Vort.	*Phil.*	*B. cal.*	*P. vul.*	*K. co.*	*T. elo.*	*B. qua.*	*Achn.*	*Apha.*	*A.gra.*	*Chlo.*	*C. men.*	*C. clo.*	*Diat.*	*P. oce.*	*Ulna.*	Ni	Co	Fe	Mn	Al	Zn	Cd
Vort.	1																						
Phil.	**0.53**	1																					
B. cal.	0.07	0.24	1																				
P. vul.	0.14	0.29	-0.20	1																			
K. co.	-0.06	0.05	-0.05	**0.57**	1																		

T. elo.	0.09	0.30	-0.07	**0.56**	-0.07	1																	
B. qua.	0.20	0.26	-0.07	-0.05	0.22	-0.17	1																
Achn.	0.05	-0.36	0.18	-0.30	-0.16	-0.24	-0.19	1															
Apha.	-0.11	-0.24	-0.14	-0.15	-0.15	-0.11	-0.25	0.03	1														
A.gra.	0.00	-0.04	-0.17	0.28	**0.47**	0.08	0.22	-0.07	0.25	1													
Chlo.	0.16	0.21	-0.19	0.06	-0.26	0.29	-0.16	-0.14	**0.66**	0.13	1												
C. men.	-0.04	-0.38	0.15	-0.32	-0.23	-0.24	-0.29	**0.94**	0.21	-0.05	0.00	1											
C. clo.	0.02	0.07	-0.19	-0.12	0.05	-0.27	0.13	0.03	-0.18	-0.13	-0.28	-0.04	1										
Diat.	-0.05	-0.20	-0.12	0.35	**0.75**	-0.22	0.11	0.11	0.07	0.36	-0.19	0.05	0.31	1									
P. oce.	-0.05	**-0.44**	-0.15	-0.06	0.37	-0.34	0.14	**0.67**	-0.15	0.38	**-0.43**	**0.54**	0.16	**0.50**	1								
Ulna.	-0.13	-0.15	-0.13	0.34	**0.76**	-0.15	0.20	0.04	-0.15	**0.61**	-0.32	-0.03	0.24	**0.84**	**0.57**	1							
Ni	-0.09	0.38	0.19	-0.01	0.19	-0.04	0.24	-0.11	-0.06	0.36	-0.12	-0.09	-0.03	-0.04	0.02	0.12	1						
Co	-0.02	-0.08	0.21	-0.20	-0.14	-0.18	-0.18	**0.45**	0.10	-0.03	0.25	**0.50**	0.00	-0.15	0.05	-0.13	0.21	1					
Fe	-0.13	-0.31	-0.35	-0.32	-0.22	-0.28	-0.10	0.14	**0.52**	0.04	0.33	0.13	0.09	-0.10	0.09	-0.16	0.02	0.36	1				
Mn	-0.15	-0.05	-0.27	-0.19	-0.02	-0.21	-0.08	-0.27	**0.58**	0.31	**0.44**	-0.20	0.37	0.15	-0.19	0.08	0.04	0.09	**0.53**	1			
Al	-0.14	-0.12	-0.02	-0.35	-0.31	-0.23	-0.15	0.08	**0.71**	-0.08	**0.53**	0.16	0.07	-0.19	-0.26	-0.39	0.08	**0.44**	**0.79**	**0.61**	1		
Zn	-0.22	-0.18	-0.30	-0.03	-0.03	0.18	-0.32	0.15	**0.61**	0.16	**0.52**	0.26	-0.24	0.03	-0.01	-0.12	0.16	0.21	**0.49**	0.27	**0.53**	1	
Cd	0.24	0.35	0.19	0.17	0.09	0.03	**0.51**	-0.17	-0.23	0.22	-0.22	-0.22	-0.16	-0.14	-0.03	0.13	0.27	-0.14	-0.24	-0.24	-0.23	**-0.50**	1

Values in bold are different from 0 with a significance level alpha=0.05

CONCLUSION

From previous results, we can conclude that the amount of agricultural and sewage water discharged to the Rosetta branch and the many pollutants it carries, especially heavy metals, negatively affect the environmental situation in the Nile River. Although the presence and flowering of phytoplankton and zooplankton in the Rosetta branch are related to the presence and abundance of nutrients, the results showed a positive relationship between plankton and heavy metals. We recommend continually evaluating the environmental status of the Nile River to monitor pollution and treat it by establishing sewage water treatment plants before discharging it into the Nile.

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