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Seasonal Variation and Correlation between the Physical, Chemical and Microbiological Parameters of Nile Water in a Selected Area in Egypt (Case study)

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Abstract:

Freshwater resources in terms of water quality is a crucial issue worldwide. In Egypt, the Nile River is the primary source of freshwater in the country and monitoring its water quality is a major task on governments and research levels. In the present case study, the physical, chemical and algal distribution in Nile River was monitored over two seasons (winter and summer) in 2019. The study aimed to check the seasonal variation among the different water parameters and also to check the correlations between those parameters. Water samples were collected from the Nile in Cairo, governorate in EGYPT. The different physicochemical and microbiological properties in water samples were assessed. The studied parameters included: temperature, turbidity, dissolved oxygen, chemical oxygen demand, pH, electric conductivity, total dissolved solids, total hardness, anions and cations. Also, the total algae count, blue-green algae, green algae, diatoms, unicellular and filamentous algae were monitored. The results revealed that during the winter season, the values recorded for (turbidity, total dissolved solids, pH, total alkalinity, total hardness, dissolved oxygen, chemical oxygen demand as well as nitrate, sulfate, chloride, fluoride ions, calcium and magnesium) were higher than during summer. While other parameters, including ammonia, nitrite, silicate, carbon dioxide, phosphate, manganese, iron and residual aluminum, were higher in summer compared to winter. The data showed a variation total algal count of 4600 to 6500 unit/ml in winter and varied from 3100 to 4500 unit/ml during the summer season with the predominance of diatoms. The recorded Pearson's correlations indicated several significant correlations between tested parameters. In conclusion, although there were several variations in, measured water quality parameters through all results were within the permissible limits set by the World Health Organization for drinking water.

Key words: Algal distribution, Correlation, Freshwater, Physicochemical parameters, Quality monitoring.

Introduction:

Freshwater sources and their quality are of utmost importance in every country around the world. The increase of population, along with economic development, is expected to increase the pressure on freshwater resources, which creates challenges for maintaining the water supply. The availability of water and change in its properties is usually affected by the climatic changes (1).

In Egypt, River Nile is the primary source for freshwater (2,3). Since the ancients time, the Nile has meant a lot to the Egyptians as it has a direct impact on the economy, health, culture, social and political lives (4). The River Nile is the longest river in the world (4,135 miles), passing through ten African countries (5).

The quality of water is usually interpreted by its physical, chemical and biological characteristics. Water quality defines water conditions concerning the necessities of one or more biotic species and or to any individual requirement or purpose (6). For any aquatic ecosystem, the physicochemical parameters of water are principle keys for the identification of its origin, quality and type. Before being used for drinking, domestic, agricultural, or industrial purposes, the physicochemical parameters are essential and important for testing the water. Water has to be tested on various physicochemical parameters., The selection of the parameters tested, depends only on the purpose of using that water and how much we need its quality and purity. Analysis of water quality is important for the protection of the natural ecosystem (7).

The various physical and chemical characteristics of water are essential for the growth and distribution of algae (8). Freshwater algae are quickly affected by any variation in their ecosystem. Thus they can be regarded as a reflectance for water quality of the ecosystem (9,10). It can be said that studying the algal abundance and distribution, as well as the physicochemical factors of its environment, is vital for the identification of the status of the water body (11).

Algae are an essential part of water quality management biomonitoring programs. Because of their nutrient requirements, rapid reproduction rate and concise life cycle they are suitable for water quality assessment. Algae are essential indicators of the environmental situation as they respond in a wide range of water situations to the qualitative and quantitative composition of species (12).

Biological measures may be a descriptive measure not just for any aquatic system's level of contamination and eutrophication phenomenon but also for the equilibrium and efficiency of the system. Also, the effect of chemical and physical conditions that arise over a prolonged period may be expressed in aquatic living populations (13). The present work is a case study aiming at the determination of the seasonal variation of water physical, chemical and microbiological parameters as well as to investigate the correlation between the studied parameters over the winter and summer seasons during 2019 in a segment of the River Nile in Al-Maadi zone, west Cairo, Egypt. The selected area is a residential area and the study location was chosen as it is around the major intake point for water treatment plants.

Materials and Methods:

Water Sampling

Surface water samples were collected from the Nile River in Maadi residential zone (29°57’58.5” N and 31°14’ 19.8” S). The sampling was done regularly during the three months of winter and three months of summer 2019. A total number of 12 sample/ month (three samples weekly) were collected from the sampling location in Fig. 1. Sampling was done using one litter sampling polyethylene plastic bottles (clean and sterile). The temperature of the samples was recorded and the bottles were labeled. Samples were then transferred to the laboratory refrigerated in an icebox and were subjected to analysis within 24 hours of collection. Sampling was done according to EPA guidelines (14).

Water analysis

The standard methods of analysis of water and wastewater (15) were employed for the determination of different physical and chemical parameters of water samples. Anions concentration in water samples was determined by ion chromatography using a Thermo Scientific™ Dionex™ ICS-5000+ Capillary HPIC™ System. Whereas the inductively coupled plasma ICP-OES Perkin Elmer optima2000 was used for cations determination. Chemical Oxygen Demand was tested using the potassium permanganate method. Total hardness and total alkalinity were measured by Titrimetric Method. The pH, electric conductivity and dissolved oxygen were determined by a multiparameter meters Thermo Scientific.

The total algae count and algae distribution in water samples were also determined, as previously described by Khalil et al. (16) and Rashad et al. (2). In brief, samples for algal count were preserved with iodine in potassium iodide (Lugol’s Solution), then algae identification was made according to Prescott, Whitford and Schumacher.

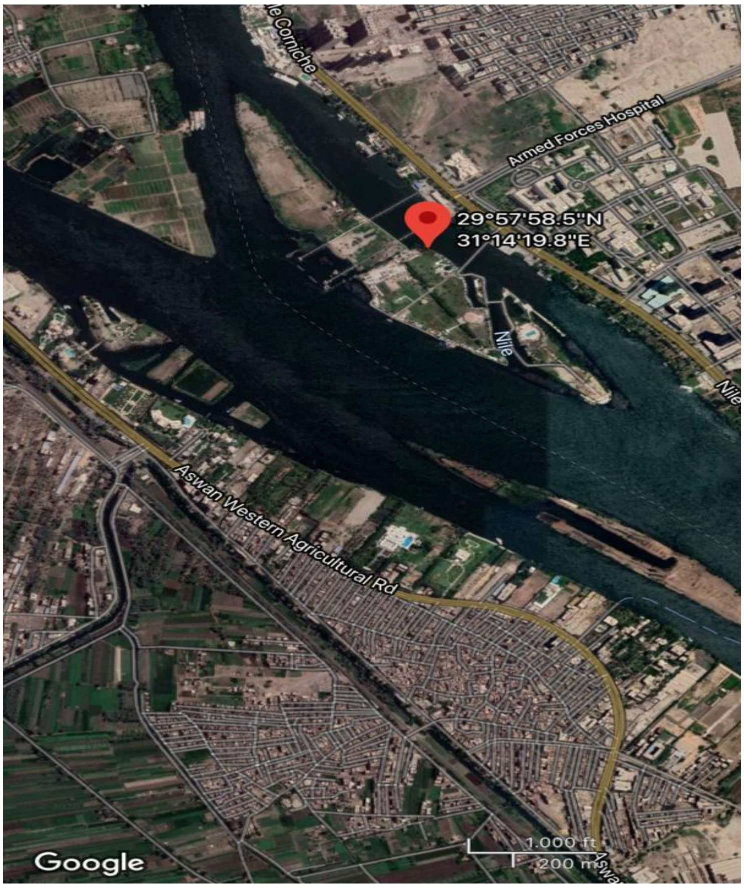

Figure 1. Sampling location in Cairo governorate

Statistical analysis

The data obtained for water's physicochemical and microbiological parameters were analyzed using "SPSS 19 software" to obtain the Pearson's correlations between various parameters.

Results and Discussion:

Seasonal variation of water physical and chemical properties

Physicochemical parameters of water are considered as a primary tool for the identification of the nature, quality and type of water (17). Table 1 shows the physical and chemical parameters recorded for water samples during winter and summer seasons during the year 2019. The results indicated that all tested parameters varied by changing the season. It was noticed that during the winter season, the values recorded for (turbidity, total dissolved solids, pH, total alkalinity, total hardness, dissolved oxygen, chemical oxygen demand as well as nitrate, sulfate, chloride, fluoride ions, calcium and magnesium) were higher in winter than during summer while other parameters including ammonia, nitrite, silicate, carbon dioxide, phosphate, manganese, iron and residual aluminum, were higher in summer compared to winter.

Data in Table 1 depicted that the lowest temperature value recorded in winter was (16.4°C) and the highest temperature recorded in summer was (31°C). Temperature is a crucial parameter of water quality because it controls aquatic life varieties and directly influences the rate of chemical and biological reactions (18). The water turbidity varied from 7.3 to 11.2 NTU, noting that the high turbidity was in winter, which is in agreement with the results of Abdel-Satar et al. (19), who reported higher turbidity in Nile water during the winter season. The high turbidity in the winter season could be explained by the possibility that during the rainy season there may be the erosion of soil carried by runoff from the surrounding areas (20).

As for pH, all values recorded (7.1 to 8.0) were within the WHO limits for drinking water (6.5-8.0) and were higher in winter as compared to summer (21). This is following previous studies concerning the Nile (22). Carbon dioxide concentration in water ranged from 8.6 in winter to 10.33 mg/L in summer. The higher CO_2 values found in summer compared to winter might be due to deoxygenation and decreased water levels during summer (20).

Total dissolved solids (TDS) in water samples had a mean value of 230 mg/l in summer and 316 mg/l in winter, which are both within the permissible limit (500mg/l) set by the WHO (21). The data of the present study show that the total hardness of water was lowest in summer109 mg/l and increased to 152 mg/l in winter. Excess of drinking water hardness is not a health hazard, but higher water hardness can aggravate the sensory properties of drinking water (23).

The total alkalinity of water ranged from 125mg/l in summer to 150 mg/l in winter. It is known that total alkalinity denotes the capability of water to resist the variations in pH and thus, the determination of alkalinity is of great importance for monitoring anthropogenic disorders disturbances (24).

The electrical conductivity (EC) values for the water samples showed a minimum value of 210µS/cm in winter and a maximum value of 390 µS/cm in summer. All values were within the WHO guidelines, where the maximum permissible EC in drinking water is 900 µS/cm (21). Dissolved oxygen (DO) is used as a water quality measure and it is an essential parameter for aerobic organism metabolism. The data in Table (1) revealed a variation in DO between 7.2 as the lowest value in summer to 9.5 mg/l as the highest value in winter. This could be due to the decreased rate of decomposition of organic matter at low temperature and low metabolic activity of aquatic organisms (25).

Table 1. Physical and chemical properties of water during summer and winter 2019

Parameter		Winter Season 2019	Summer Season 2019	Parameter		Winter Season 2019	Summer Season 2019
Turbidity	Low	7.3	7.3	**SiO_2**	Low	1.2	1.1
(NTU)	High	11.2	9.8	**(mg/L)**	high	3.2	5.6
	mean	**9.43**	**8.6**		**mean**	**2.48**	**4.15**
Temperature	Low	16.4	23	**COD**	Low	2	1.7
(°C)	High	24.2	31	**(mg/L)**	high	2.8	2.5
	mean	**19.4**	**27.66**		**mean**	**2.33**	**2.3**
TDS	Low	255	210	**DO**	Low	7.8	7.2
(mg/L)	High	352	260	**(mg/L)**	high	9.5	8.3
	mean	**316**	**230**		**mean**	**8.86**	**7.63**
EC	Low	210	320	**CO_2**	Low	8	8
(µS/cm)	High	260	390	**(mg/L)**	high	11	12
	mean	**240**	**347**		**mean**	**8.66**	**10.33**
pH	Low	7.3	7.1	**PO_4**	Low	0.014	0.1
	High	8.0	8.0	**(mg/L)**	high	0.1	0.2
	mean	**7.61**	**7.81**		**mean**	**0.054**	**0.11**
NH_3-N	Low	0.1	0.2	**F**	Low	0.35	0.4
(mg/L)	High	0.4	0.4	**(mg/L)**	high	0.6	0.5
	mean	**0.21**	**0.27**		**mean**	**0.46**	**0.44**
NO_2	Low	0.01	0.01	**Fe**	Low	0.2	0.1
(mg/L)	High	0.03	0.04	**(mg/L)**	high	0.25	0.23
	mean	**0.025**	**0.045**		**mean**	**0.24**	**0.2**
NO_3	Low	0.04	0.1	**Mn**	Low	0.02	0.02
(mg/L)	High	4.6	0.9	**(mg/L)**	high	0.2	0.2
	mean	**1.67**	**0.4**		**mean**	**0.10**	**0.09**
Total	Low	136	125	**Residual Al**	Low	0.08	0.07
Alkalinity	High	150	140	**(mg/L)**	high	0.1	0.1
(mg/L)	**mean**	**144**	**135**		**mean**	**0.09**	**0.08**
Total	Low	120	109	**Ca**	Low	25	24
hardness	High	152	120	**(mg/L)**	high	34	29
(mg/L)	**mean**	**137**	**117**		**mean**	**29.53**	**26.73**
SO_4	Low	15	14	**Mg**	Low	12.4	11
(mg/L)	High	38	34	**(mg/L)**	high	17	15.3
	mean	**27.66**	**21**		**mean**	**15.08**	**13.08**
Cl	Low	20	16				
(mg/L)	High	37	26				
	mean	**28.66**	**20.66**				

The chemical oxygen demand (COD) is usually regarded an indicator for determining the level of water pollution (6). The WHO sets the permissible limit for COD as 40mg/l (21). As seen in Table (1), COD values obtained during the present study were all within the permissible limits and ranged from 1.7 to 2.8 mg/l.

Table 1 also depicted the variation of ammonia (0.1-0.4 mg/l), nitrate (0.04-4.6 mg/l) and nitrite (0.01-0.08 mg/l) in water samples. Ammonia is a type of nitrogen compound found in nature and is important for living organisms to grow and reproduce. In contrast, nitrate and nitrite in drinking water can have negative human health impacts (26). The presence of nitrates in water could be a result of anthropogenic activities such as runoff water from agricultural lands and discharge of household at the study site (20).

From Table 1, the concentration of available phosphate ions showed a variation between 0.014 mg/l to 0.2 mg/l, with the lowest levels recorded during the winter season. A variation in sulfate ions concentration was also observed with a mean value of 26.5 mg/l in winter and 24 mg/l in summer. Chloride and fluoride had higher concentrations in winter compared to summer recording a variation from 16 to 37mg/l for (Cl^-) and 0.35 to 0.6 mg/l for (F^-). According to El-Feky et al. (6), the rates of anions and cations in water differ naturally depending on climatic and geographic conditions.

Ca and Mg are essential intracellular cations involved in many enzymatic processes. They are important for different biological processes (27). On the other hand, a high concentration of calcium and magnesium ions causes water hardness (28). Data in Table 1 show that the minimum concentrations of calcium and magnesium were obtained during summer (24 and 11 mg/l, respectively) and the highest concentrations were found during the winter season (34 and 17 mg/l, respectively). Similar findings were reported by 29, who stated that the lowest values of Ca were recorded in the hot seasons and the highest in the cold seasons, which might be attributed to the solubility decrease of $CaCO_3$ as the temperature increase. Data in Table (1) show that Fe and Mn in water have a concentration of 0.1-0.3mg/l and 0.02-0.2mg/l, respectively. Iron and manganese are the most common metals found in nature and their limits set by the WHO for drinking water are 1mg/l and 0.4 mg/l, respectively (19). The silicate concentration in water samples changed between 1.1 mg to 5.6 mg/l without defined seasonal trends in agreement with the previous report of Abdel-Satar (29).

Seasonal changes in the microbiological properties of water

Figure 2 represents the variation of the number of algae and their distribution in Nile water in the study area during the summer and winter seasons of the year 2019. The data showed a variation total algal count of 4600 to 6500 unit/ml in winter and varied from 3100 to 4500 unit/ml during the summer season. The data also indicated the predominance of diatoms, which ranged from 3700 to 5700 unit/ml in winter and 2200 to 3600 unit/ ml in summer. According to (30), diatoms are the most dominant and diversified group present in good numbers during four seasons, especially in fall and winter seasons followed by green algae. Blue-green algae and green algae, which are considered the least predominant species in the Nile, recorded in winter a mean number of 250 and 650 unit/ml, respectively, while their mean counts during summer were 395 and 575 unit/ml, respectively. These results agree with the early report (23). Regarding the total number of filamentous and unicellular algae, the data indicated that they were higher in winter (2275 and 2375 unit/ml, respectively) and lowest in summer (1625 and 1150 units/ml. respectively).

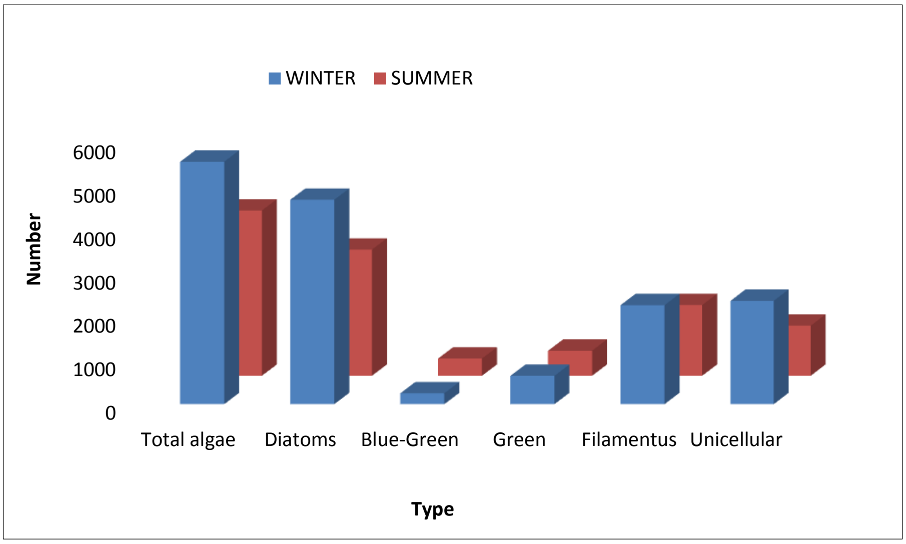

Figure 2. Seasonal variation in algae number and species

Correlation between different water parameters

The alga distribution and the number are a direct indicator for water composition (12) and thus, examining the correlation between an alga and physicochemical properties of water are significant. According to (31), correlation is an evaluation to know the degree of interrelation and association between two or more variables. Finding the correlation coefficients of the water quality parameters not only helps to assess the overall water quality but also provides information for the implementation of rapid water quality management programs.

The data obtained during the present study were statistically analyzed to evaluate the correlation between physical, chemical and microbiological parameters in water and the collected data are presented in Table 2. Regarding the interrelationships between physicochemical water parameters, the data showed that the turbidity has a significantly positive correlation with TDS, pH, EC, total hardness, Ca, Mg, SO_4, COD, DO, CO_2 and residual aluminum. The temperature of the water had a negative correlation with TDS, EC and hardness while it recorded a positive correlation with all other tested parameters. Hardness is mainly because of calcium and magnesium; also, permanent hardness is due to chloride and sulfate (32). Significant positive correlations were obtained for hardness and Ca, Mg, DO and COD. The total dissolved solids (TDS) showed a negative correlation with PO_4 concentration and a positive correlation with all other studied parameters. It can be noted that very high and a significant positive correlation was obtained for TDS and EC, hardness, Ca, Mg, DO and COD. Positive correlations were obtained for EC and all tested parameters Significant positive correlations were obtained for EC and hardness, Ca, Mg, DO and COD. Sudarshan et al. (32) stated that electrical conductivity is directly correlated with the total dissolved solids.

Table 2. Correlation between physical, chemical and microbiological parameters in water

		Turbidity	Temperature	TDS	EC	pH	Hardness	Ca	Mg	SO_4	PO_4	COD	DO	CO_2	Residual Al	Total Algae	diatoms
Turbidity	Pearson Correlation	1															
Temperature	Pearson Correlation	.471	1														
	Sig. (2-tailed)	.345															
TDS	Pearson Correlation	.838	-.085	1													
	Sig. (2-tailed)	.037	.873														
EC	Pearson Correlation	.819	-.119	.999	1												
	Sig. (2-tailed)	.046	.823	.000													
pH	Pearson Correlation	.964	.544	.761	.740	1											
	Sig. (2-tailed)	.002	.265	.079	.093												
Hardness	Pearson Correlation	.819	-.117	.995	.996	.718	1										
	Sig. (2-tailed)	.046	.826	.000	.000	.108											
Ca	Pearson Correlation	.976	.269	.936	.923	.914	.925	1									
	Sig. (2-tailed)	.001	.607	.006	.009	.011	.008										
Mg	Pearson Correlation	.975	.355	.888	.873	.974	.855	.973	1								
	Sig. (2-tailed)	.001	.490	.018	.023	.001	.030	.001									
SO_4	Pearson Correlation	.983	.583	.755	.732	.992	.721	.928	.965	1							
	Sig. (2-tailed)	.000	.225	.083	.098	.000	.106	.008	.002								
PO_4	Pearson Correlation	.391	.996	-.172	-.205	.475	-.205	.182	.276	.512	1						
	Sig. (2-tailed)	.443	.000	.745	.696	.341	.697	.730	.597	.299							
COD	Pearson Correlation	.964	.330	.893	.879	.970	.858	.968	.999	.956	.251	1					
	Sig. (2-tailed)	.002	.524	.017	.021	.001	.029	.002	.000	.003	.631						
DO	Pearson Correlation	.921	.096	.983	.976	.867	.969	.981	.957	.862	.010	.959	1				
	Sig. (2-tailed)	.009	.856	.000	.001	.025	.001	.001	.003	.027	.986	.003					
CO_2	Pearson Correlation	.850	.801	.475	.446	.931	.422	.726	.826	.930	.755	.815	.629	1			
	Sig. (2-tailed)	.032	.056	.342	.376	.007	.405	.102	.043	.007	.083	.048	.181				
Residual Al	Pearson Correlation	.921	.495	.747	.728	.989	.693	.877	.962	.961	.431	.964	.850	.917	1		
	Sig. (2-tailed)	.009	.319	.088	.101	.000	.127	.022	.002	.002	.394	.002	.032	.010			
Total Algae	Pearson Correlation	.196	-.511	.556	.571	.259	.517	.330	.380	.169	-.542	.412	.484	.008	.351	1	
	Sig. (2-tailed)	.709	.300	.252	.237	.620	.293	.523	.457	.749	.266	.416	.331	.988	.495		
Diatoms	Pearson Correlation	.178	-.514	.537	.553	.241	.499	.311	.361	.152	-.544	.394	.464	-.005	.334	1.000	1
	Sig. (2-tailed)	.735	.297	.272	.256	.645	.313	.549	.482	.774	.265	.440	.353	.993	.518	.000	

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Also, positive correlations were found for pH and all monitored water parameters with significant positive correlation for Ca, Mg, SO_4, DO, COD, CO_2 and residual Al. Other notable positive correlations were obtained for hardness with calcium, magnesium, COD and DO as well for calcium with magnesium, sulfate, COD, DO and residual Al. Magnesium and also sulfate concentrations in the water had significantly positive correlations with all studied parameters except PO_4. COD had strong significant positive correlations with DO, CO_2 and residual Al; also, CO_2 and DO had both significant positive correlations with residual Al. Dissolved oxygen is correlated to the water temperature, water agitation, types and number of aquatic plants, light penetration and amount of dissolved or suspended solids (32).

For the correlation between total algae and diatoms counts and the different physicochemical parameters of water, data revealed a positive correlation between the total alga count and turbidity, TDS, EC, total hardness, Ca, Mg, SO_4, COD, DO, CO_2 and residual aluminum, while the negative correlation was observed for total algal count and water temperature and PO_4 concentration. A similar trend was attained for the diatoms number, which showed a positive correlation with all water physicochemical parameters except temperature, PO_4 concentration and CO_2. The data also revealed a significant positive correlation between the total number of algae and diatoms' count in water. The results of the present study are in agreement with several previous studies. According to El-Outify and Iskaros (33), the drop in water temperature during the winter season favors the growth of diatoms and this rise has been reflected in the increase of algal densities. The differences in pH levels may be due to algal photosynthesis. The pH value is also strongly regulated by the rate of CO_2 consumption through photosynthetic activities of the phytoplankton. Also, (34) concluded that an increase in TDS increases the apparent color of the water, water temperature and decreases the rate of photosynthesis

Conclusion:

Regular monitoring of water quality parameters is important for early detection of any alterations that may occur. The present study aimed at monitoring the physicochemical and biological characteristics of surface water from River Nile in Cairo, collected during winter and summer seasons in 2019. The algal distribution indicated the predominance of diatoms followed by the blue-green and green alga. Different correlations were obtained between total algae and diatoms counts and the various physicochemical parameters of water. It was found that there are positive correlations between the total alga count and most of the measured physicochemical parameters, whereas negative correlations were obtained for total algal count and water temperature and PO_4 concentration. In general, there were several variations in measured water quality parameters; nevertheless, all results were within the permissible limits set by the World Health Organization for drinking water.

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours.
- Ethical Clearance: The study does not involve any experiments on animals or humans.

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التباين والارتباط الموسمي بين المعايير الفيزيائية والكيميائية والميكروبيولوجية لمياه النيل في منطقة مختارة في مصر (دراسة حالة)

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الخلاصة:

تعد جودة موارد المياه العذبة قضية حاسمة في جميع أنحاء العالم. وفي مصر، يعد نهر النيل المصدر الرئيسي للمياه العذبة في البلاد، ورصد جودة المياه هي مهمة رئيسية على مستوى الحكومات والمستوى البحثي. وفي الدراسة الحالية، تم رصد التوزيع الفيزيائي والكيميائي والطحالب في نهر النيل على مدى موسمين (الشتاء والصيف) في عام 2019. كانت أهداف الدراسة هي التحقق من التباين الموسمي بين معايير المياه المختلفة والتحقق من الارتباط بين تلك البيانات. تم جمع العينات من مياه النيل بمحافظة القاهرة بمصر. تم تقييم الخصائص الفيزيوكيميائية والميكروبيولوجية المختلفة في عينات المياه. وقد تضمنت المعاملات التي تم دراستها الاتي: درجة الحرارة، نسبة العكاره، الأكسجين المذاب، الطلب على الأكسجين الكيميائي، الأس الهيدروجيني، التوصيل الكهربائي، إجمالي المواد الصلبة الذائبة، الصلابة الكلية، الأنيونات والكاتيونات. كما تم رصد إجمالي عدد الطحالب ، الطحالب الخضراء المزرقة ، الطحالب الخضراء ، الدياتومات ، الطحالب أحادية الخلية والخيطية. وقد أظهرت النتائج أنه خلال فصل الشتاء كانت القيم المسجلة لـ (العكارة، إجمالي المواد الصلبة الذائبة، الرقم الهيدروجيني، القلوية الكلية، الصلابة الكلية، الأكسجين المذاب، الطلب على الأكسجين الكيميائي بالإضافة إلى النترات، الكبريتات، الكلوريد، أيونات الفلورايد، الكالسيوم والمغنيسيوم) أعلى من القيم المسجلة خلال فصل الصيف. في حين كانت المعاملات الأخرى بما في ذلك الأمونيا والنتريت والسيليكات وثاني أكسيد الكربون والفوسفات والمنجنيز والحديد والألمنيوم المتبقي أعلى في الصيف مقارنة بالشتاء. أظهرت البيانات تباين إجمالي عدد الطحالب من 4600 إلى 6500 وحدة / مل في الشتاء وتراوح من 3100 إلى 4500 وحدة / مل خلال موسم الصيف مع هيمنة الدياتومات. تشير ارتباطات Pearson المسجلة إلى العديد من الارتباطات المهمة بين المعاملات المختبرة. في الختام، على الرغم من وجود العديد من الاختلافات في معايير جودة المياه المختبرة الا أن جميع النتائج كانت ضمن الحدود المسموح بها التي وضعتها منظمة الصحة العالمية لمياه الشرب.

الكلمات المفتاحية: المياه العذبة؛ المعاملات الفيزيائية الكيميائية. توزيع الطحالب مراقبة الجودة؛ معامل الارتباط