INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 4, No. 2, p. 68-80, 2014
http://www.innspub.net

RESEARCH PAPER | OPEN ACCESS

Alternations in biochemical structures of phytoplankton in Aswan Reservoir and River Nile, Egypt

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Article published on February 03, 2014

Key words: Aswan Reservoir, River Nile, phytoplankton, biochemical contents, pollution.

Abstract

River Nile is an important resource for sustaining life. This study was carried out at Aswan Reservoir and the main stream of River Nile and focused on the seasonal and spatial variation of biochemical composition of phytoplankton and the effect of changes in physico-chemical parameters and different pollutants on it. Water samples were collected from fifteen sampling sites, where four sites from Aswan Reservoir and eleven from the main stream of River Nile and some of its drains from spring 2008 to winter 2009. The results of the environmental parameters showed wide variations in their concentrations along the different sites of the reservoir and River Nile. Data of phytoplankton biochemical contents in Aswan Reservoir gave the maximum contents of lipid in summer (16.6 mg/l), while the optimum season for proteins was winter (5.6 g/l), the clearest sites of the reservoir (R3 and R4) gave the maximum average values of carbohydrates and proteins. The study showed that the maximum yield of chlorophyll a and carbohydrate contents was obtained in spring for both Aswan Reservoir and River Nile, while the major peak for both lipids and proteins of River Nile obtained in winter (10.34 mg/l and 6.06 g/l, respectively). The total biochemical contents (lipids, proteins and carbohydrates) are inhibited at drains of Kima, Com Ombo, Qus, Etsa and El-Hawamdia then elevated again by getting far away from the pollution source. It is concluded that the environmental parameters and different pollutants are the main factors controlling the biochemical contents of phytoplankton.

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Introduction

River Nile is the life artery of Egypt, the Nile is the only permanent river that manages to cross the Sahara, the largest desert in the world, and reach the Mediterranean Sea; the Nile basin covers the whole of Egypt, Sudan and one third of Ethiopia (Tudorancea and Tayor, 2002; Eltahir, 2004). Egypt is therefore totally dependent on the Nile for their freshwater needs (Allan, 2009).

The characteristics of the Nile ecosystem clearly reflect the impact of river flow control and can be categorized into three regions: the Aswan reservoir, the river from Aswan to Cairo and the Delta. However, the construction of the High Dam resulted in great modification in the hydrodynamic regime of River Nile, with significant changes in physico-chemical and biological characteristics of the downstream water and this is believed to have changed the conditions for aquatic organisms (Fishar and Khalifa, 2003; Fishar *et al.,* 2006). The water quality in the Nile downstream from Aswan has changed dramatically as the Nile water became silt-free, less turbid and with considerably less velocity (Saad and Goma, 1994). According to the National Water Research Center (NWRC, 2000) and Wahaab and Badawy (2004) River Nile from Aswan to El-Kanater Barrage receives wastewater discharge from 124 point sources, of which 67 are agricultural drains and the remainders are industrial sources and domestic wastewater hence make such water unsuitable for aquatic life. The water quality of the main part of River Nile from Aswan to Delta barrage is good inspite of the high organic and inorganic loads discharged from some drains and industrial activities (Agricultural Policy Reform Program, 2002). But Masoud *et al.,* (2002); World Bank (2005) and El-Sheikh *et al.,* (2010) mentioned that the water quality released from the Aswan High dam shows little degradation and remains remarkably clean from chemical pollution until it reaches the Delta, nevertheless, the river is still able to self-purify in virtually all the locations, with very little exception. Therefore, optimizing the quantity and quality of Nile water is the main concern of any strategic planning for better water resources management in Egypt.

Talling *et al.,* (2009) reported that several reasons may lead to vigorous and varied developments of planktonic algae in regions of the Nile system. First, there are large headwater lakes in which lacustrine phytoplankton can develop, and possibly travel down their outflows as potential 'inocula' for renewed growth downstream. Second, the retention of water in the reservoirs within the Sudan and in Egypt provides the additional time favorable for phytoplankton development to which marginal retentions also contribute. Third, the great length of the river and its component stretches increase the time of travel of any water-mass and so the opportunities for planktonic growth, phytoplankton is widely but unevenly developed in regions of the Nile system. Hammad and Ibrahim (2012) reported that community composition in River Nile is mostly dominated by diatoms (e.g. Aulacoseira granulata) or Cyanobacteria (e.g. Anabaena flos-aquae f. spiroides), but there are many species of green algae and some flagellates (e.g. Pediastrum, Volvox).

Biomass of micro-algae is a good source of nutrients, biologically active ingredients and considered the primary producers in the aquatic environment. Any change in their type, distribution and concentration would affect all organisms living in the Nile's water; accordingly, estimation of algal biomass is very crucial (Shehata *et al.,* 2008; Sobhy, 2008). The discharged pollutants affect the biochemical composition of phytoplankton, which showed its reliable biomarker of specific water quality problems, thus biochemical approaches for the detection of environmental pollutants in microalgae should be seriously considered in any environmental assessment program (El-Attar, 2000; Okay et al., 2000; Abd El-Hady, 2008). The purpose of this study is to document the changes in phytoplankton biochemical structures at Aswan Reservoir and River Nile according to the effect of pollution and variation in environmental factors.

Materials and methods

Sampling locations

Water samples were collected from fifteen sampling sites from Aswan Reservoir to El-Waraq in Cairo and from five selected drains at River Nile sites (Kima, Com Ombo, Qus, Etsa and El-Hawamdia). Seasonal sampling program took place from spring 2008 to winter 2009.

Aswan Reservoir

It stretched 3,830 meters (12,570 ft) long, 111 meters (364 ft) tall, 980 meters (3,220 ft) wide at its base and 40 meters wide on top (Biswas and Tortajada, 2012) and its spillway capacity is 11,000 cubic meters per second (390,000 cu ft/s). Four sites from Aswan Reservoir (R 1 - 4) were chosen (Fig. 1).

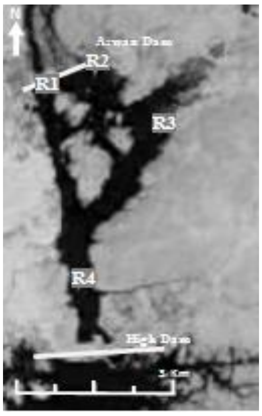


Fig. 1. Sampling sites at Aswan Reservoir.

River Nile

River Nile, with an estimated length of over 6800 Km, is the longest river flowing from south to north over 35 degrees of latituide (FAO, 1997). Eleven sites from the main stream of River Nile (from Kima to El-Waraq) were collected (Fig. 2).

Physico-chemical characteristics

Temperature, pH, transparency, Electrical conductivity and dissolved oxygen were measured in situ. Water temperature was measured by an ordinary thermometer, pH by Orion Research Ion Analyzer 399A pH meter and transparency by Secchi disc. Electrical conductivity was measured using Hydro-Lab., "Multi 340 II SET". Dissolved oxygen (DO) was determined by azide modification method as specified in APHA (1998).

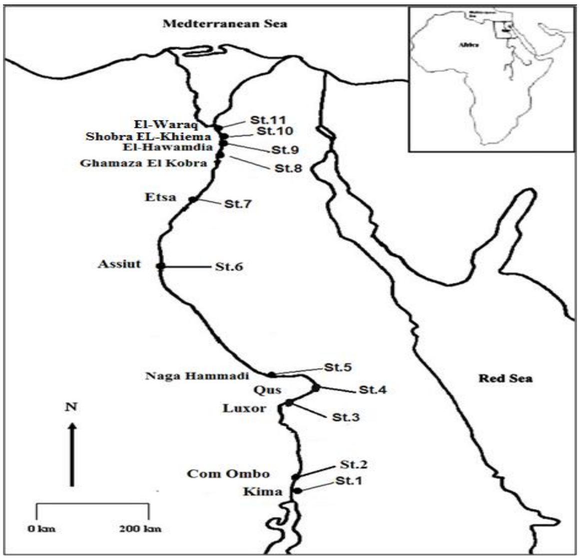


Fig. 2. Sampling sites along River Nile.

Biochemical analysis

At each site water samples were collected by plastic bottles, then sieved and filtered through zooplankton net (100 µm mesh size) to separate macrozooplankton. Then 10 ml of the filtered water was refiltered on Whatman GF/F (0.7 µm pore diameter) fiber circles and the samples were transferred to the laboratory in ice tanks to determine the biochemical parameters of the separated phytoplankton. Chlorophyll a values were measured according to standard method (APHD, 1995). Total protein content was determined by Biuret method (David and Hazel, 1993), whereas, the total lipid content was analyzed by the Sulphophosphovanillin procedure (SPV) (Chabrol and Castellano, 1961). Carbohydrate contents were measured according to Phenol-sulphuric acid method as described by Dubois *et al.,* (1956). The statistical analysis was performed using Primer 5 program (2001).

Results and discussion

Physico-chemical characters of Aswan Reservoir and River Nile

Water temperature showed a noticeable seasonal trend with a lowest value (17.10C) recorded in winter and a highest (30.70C) in summer; Abdel-Satar (2005) showed that water temperature of River Nile plays an important role for the heat budget of the Nile water, Mohammed *et al.,* (1986) found that temperature is a key factor which regulates River Nile phytoplankton population. The results showed that transparency values increased in summer (70-250 cm), this elevation in transparency might be attributed to the increase in intensity of solar radiation penetrating the surface water (Abdel-Satar, 2001). The negative correlation between water transparency and chlorophyll a showed that light conditions in the Aswan High Dam Reservoir seemed not to be a limiting factor for phytoplankton development (Salem, 2011). The obtained results of total dissolved soiled (TDS) showed an increase in spring (103-308 mgl-1), TDS maintained positive relationships with Cl-, SO42-, HCO3-, Na, K, Ca and Mg and negative correlation with River Nile transparency during most seasons (Abdel-Satar, 2005). The decrease in the dissolved salts in Aswan High Dam Reservoir could be related to the adsorption of dissolved salts in the surface of suspended particles coming with flood water and precipitated to bottom sediment (Toufeek and Korium, 2009). Data observed that the highest EC value was recorded in winter (375 mS/cm), while the lowest value was in spring (222 mS/cm), Abd El-Hady and Hussian (2012) illustrated that winter was the optimum season for EC in Ismailia Canal. The pH is an important environmental factor, it is a plant-growth-limiting factor and the change in pH is directly related to the availability and absorption of nutrients from solution. pH values in the present study were in the alkaline side (7.03-8.5), small local differences were observed with no clear seasonal variations and the optimum pH value obtained in spring (8.05), George and Heaney (1978) suggested that high pH values promote the growth of phytoplankton and result in bloom. The study indicated that dissolved oxygen values (DO) ranged from 1.88 to 13.20 mgl-1, with remarkable seasonal and local variations, the decrease in DO in summer might be due to the elevation of water temperature and the increase in oxidative processes of organic matter (Abdel-Satar and Elewa, 2001), Gharib and Abdel-Halim (2006) showed that oxygen in Lake Nasser exhibits a close correlation with phytoplankton abundance and phytoplankton biomass.

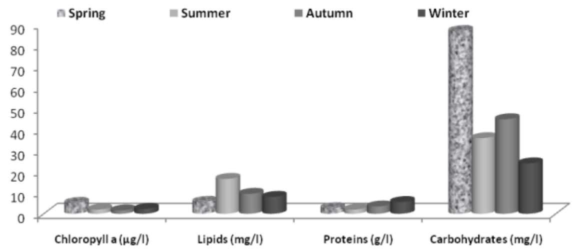


Fig. 3. Seasonal variations in phytoplankton biochemical contents at Aswan Reservoir (from spring 2008 to winter 2009).

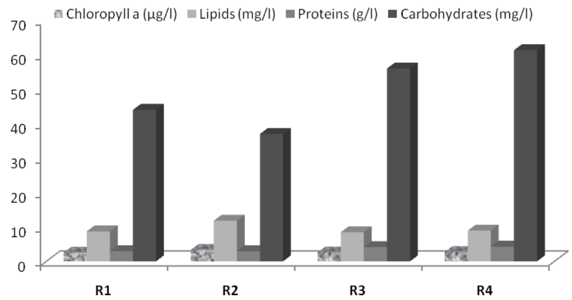


Fig. 4. Regional variations in phytoplankton biochemical contents along the four seasons at Aswan Reservoir.

Biochemical structures of phytoplankton

Phytoplankton biochemical contents at Aswan Reservoir

The impacts of the construction of the High Aswan Dam can be classified into four broad categories: physical, biological, economic and social (Biswas and Tortajada, 2012). The number of phytoplankton species increased with reservoir age (Abd El-Karim, 2005), Samaan (1974) recorded the presence of 27 species and its number increased to 94 in the study of Ibrahim and Mageed (2005). Phytoplankton composition in the reservoir belonged to Bacillariophyceae, Cyanophyceae, Chlorophyceae, Dinophyceae and Eugelnophceae. The dominant diatoms were Cyclotella spp., Aulacoseira and Melosira spp., while blue-greens were dominated by Lyngbya spp., Oscillatoria spp. and Anabaenopsis cunningtonii. Green algae were dominated by Ankistrodesmus spp. and Closterium spp. (Salem, 2011).

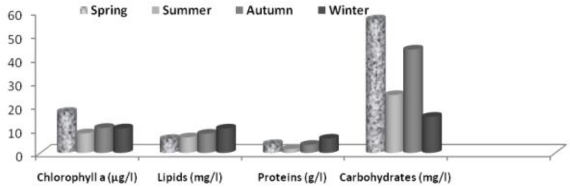


Fig. 5. Seasonal variations in biochemical contents of River Nile phytoplankton (from spring 2008 to winter 2009).

Data of biochemical contents of phytoplankton at Aswan Reservoir (Fig. 3) showed that the maximum content of lipids was in summer (16.6 mg/l). The result coincided with that of Ezz El-Deen (2006) in River Nile and Abd El-Hady and Hussian (2012) in Ismailia Canal which detected the maximum value of lipids in summer. The nutrients (phosphates and nitrates) presumably from agricultural run-offs or flushes from the Aswan Dam were probably taken up by rapid algal and macrophyte growth in summer (Fishar *et al.,* 2006). The optimum season for proteins was winter (5.6 g/l) and the lowest value was obtained in summer (1.99 g/l), Torres *et al.,* (2008) suggested that extremes of environmental factors such as temperature and oxygen trigger changes in the transcript levels of numerous genes encoding proteins in algae. The obtained results gave maximum yield of chlorophyll a and carbohydrates in spring (5.2 µg/l and 87 mg/l, respectively), the increase in pH values of River Nile water during spring season might be due to the dense vegetation and phytoplankton, which were accompanied by photosynthetic activity with expected pH elevation (Sabae, 2004). River Nile water was oxygenated during the study period, the highest values was recorded in both winter (8.06 mgl-1) which may be due to decrease in water temperature followed by spring (7.94 mgl-1) which corresponding to the flourishing of phytoplankton (Anon, 2007). Thus the cellular composition of Aswan Reservoir phytoplankton is subject to considerable variation due to changes in the physiochemical environment.

Figure 4 showed that the clearest sites R3 and R4, which are far away from any pollution sources, gave the maximum average values of carbohydrates (56 and 61.33 mg/l, respectively) and proteins (4.13 and 4.26 g/l, respectively). During the study, the maximum level of nitrate was recorded at site R4 in spring, summer and autumn seasons (180.69, 19.5, 66.91µg/l, respectively) and at site R3 in winter (83.79 µg/l) this enrichment of total inorganic nitrogen caused elevation in total protein content at the same sites. The most credible hypothesis that reported by many authors is the elevation of protein content with increase of nutrient especially nitrogen (Daume *et al.,* 2003; Sarthou *et al.,* 2005) and Uriarte et al., (2006) reported that elevated nitrogen content in growth medium would result in a higher protein content of benthic diatom. Higher enrichment of total inorganic phosphorus attained at site R3 of reservoir (495 and 41.8 µg/l in spring and autumn, respectively) and site R4 (99 µg/l in summer) caused an elevation in carbohydrates. Diatoms of Lake Manzala had the ability to produce carbohydrates which used as a food source for the heterotrophic consumer (Brouwer *et al.,* 2003; Hanlon *et al.,* 2006).

Phytoplankton is widely but unevenly developed in regions of the Nile system, it mainly dominated by Bacillariophyta (diatoms) all the year round followed by Chlorophyta, Cyanophyta, Euglenophyta and Dinophyta. Diatoms community was represented by 45 species and forming 30.8 - 82.7% of total phytoplankton standing crop recorded in Nile water samples, including Cyclotella meneghiniana, Melosira granulate and Melosira granulata v. angustissma, and secondarily by pinnate forms where Synedra ulna and other Synedra spp. contributed with the highest share, this dominance of diatoms might be attributed to the recognized occurrence of iron and silicon in Nile water (Shehata *et al.,* 2009; El-Sheekh *et al.,* 2010; Hammad-Doaa and Radi, 2010; Shehata and Badr, 2010).

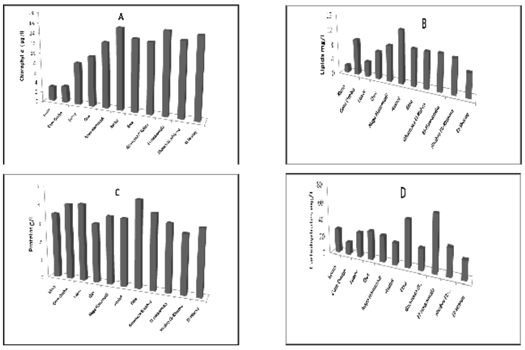


Fig. 6 (A-D). Total biochemical contents of phytoplankton at different selected sites of River Nile along the four seasons.

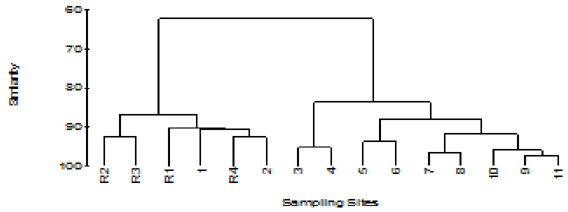
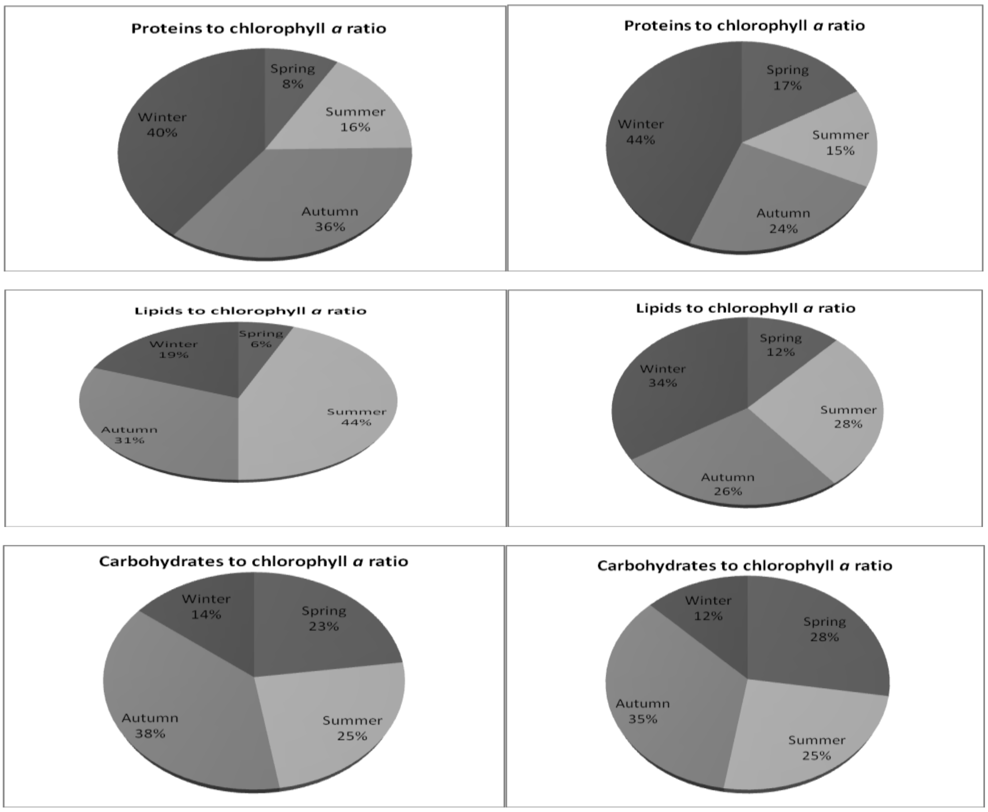


Fig. 7. Cluster analysis of the studied sampling sites according to chlorophyll a data.

Phytoplankton biochemical contents in the main stream of River Nile

The results showed that the lipid peaked in winter (10.34 mg/l) and the minimum values occur in spring (5.93 mg/l) as shown in figure 5. Lipids and silica derived principally from diatoms, which represent the main class of River Nile phytoplankton (Hammad and Ibrahim, 2012). Lipids of phytoplankton were examined in two freshwater lakes (Onondaga Lake and Lake Erieto) determine their role as indicators of algal biomass and composition, suggested that fatty acids can be utilized as biomarkers in different aquatic environments (FitzPatrick and Sarah, 2009). Also, winter was the optimum season for protein contents (6.06 g/l), while the maximum level of chlorophyll a and total carbohydrate concentration was found in spring reached 5.2 μg/l and 56.67 mg/l, respectively. Chlorophyceae and Cyanophyceae formed 17.08% and 11.81% of phytoplankton flourished in River Nile in spring, this attributed to the increase in numbers of Microcystis aeruginosa in this season (Ezz El-Deen, 2006). Cyanobacteria isolated from River Nile contain different sugar unit of polysaccharide content which include sugars such as glucose, galactose, mannose, fructose, xylose, glacturonic acid, sucrose and fucose, it emphasized that Spirulina platensis have the highest total carbohydrate content (Abdo *et al.,* 2010). The present results referred to an increase in total solids (TS) values in spring (324-552 mgl-1) for all sites at River Nile which is probably due to the phytoplankton blooming (Abdel-Satar, 1998 and Abdel-Satar, 2005). The study indicated that both chlorophyll a and total protein content were declined in summer, which associated with maximum count of zooplankton which counted 880289 Ind. m-3 (Klalifa, personal communication). Zooplankton can consume a substantial portion of the phytoplankton (Khalifa and Abd El-Hady, 2010). Thus the results indicated that the phytoplankton biochemical compositions of River Nile are variable in different seasons.

Fig. 6 (A, B, C and D) showed the total biochemical contents at the selected sites of River Nile, the results indicated that, all sites exceed in their chlorophyll a values comparing with that of Aswan Reservoir, reached maximum value at El-Hawamdia (16.13 μg/l). Talling *et al.,* (2009) mentioned that the nutrients (PO4 and NO3) are often suspected of limiting algal production in freshwaters and can be severely depleted during the growth of phytoplankton in parts of the Nile system, which reached in this study at El-Hawamdia 38.22 μg/l and 61.60 μg/l for PO4 and NO3, respectively. Gharib and Abdel-Halim (2006) showed that PO4 contributing 28.52% of the variations of the total phytoplankton abundance in Lake Nasser. Data showed that there is no clear difference between the average values of lipids and proteins of the selected sites at River Nile and that obtained in the clearest sites (R3 and R4) at Aswan Reservoir, except at Kima and Luxor which showed sharp decrease in total lipid contents (2 and 4 mg/l). Also, the obtained results indicated that the all selected sites decreased in their total carbohydrate contents than that of sites R3 and R4 at Aswan Reservoir except Etsa and El-Hawamdia which recorded the maximum level for carbohydrates (52 and 62 mg/l, respectively).



[A] [B]

Fig. 8. Phytoplankton biochemical contents to chlorophyll a ratio of both Aswan Reservoir [A] and River Nile [B].

Cluster analysis (Fig. 7) of chlorophyll a measures at each studied site revealed two main clusters, each one contained two groups. First cluster comprised sites of Aswan Reservoir in addition to sites 1 and 2 in the main Nile stream, the other cluster contained the remaining sites of River Nile (3-11). The similarity within sites of the second group were higher than that of the first cluster, the highest similarity (97.4%) was recorded between sites 9 and 11, and these two sites within site 10, followed by similarity between sites 7 and 8 (96.7%). It appeared that the nearby sites had nearly similar chlorophyll a content may be due to similarity in their phytoplankton community in these sites. Positive relation was observed between the fluctuations of total chlorophyll contents of the phytoplankton and those of total number of individuals at all investigated stations of Rosetta Branch of River Nile (Shaaban *et al.*, 2011).

Impact of different pollutants from some drains of River Nile on phytoplankton biochemical contents

It is estimated that more than 400 factories continue to discharge more than 2.5 million m3 per day of untreated effluent into Egypt's waters caused chemically and microbiologically degraded water quality (El Sheekh, 2009; Rabeh, 2009). On the other hand Sobhy (2008) mentioned that algae of River Nile such as Cyclotella ocellata, Melosira (= Aulacoseira) granulata, Nitzschia palea, Nitzschia paleacea, Aulacoseira granulata var. angustissma (diatoms) and Microcystis aeruginosa, M. flos-aquae, Chroococcus minutus and C. dispersus (Cyanobacteria) tolerate many types of pollution.

Five drains had been selected at River Nile sites (Kima, Com Ombo, Qus, Etsa and El-Hawamdia) to study changes in biochemical contents of phytoplankton. The obtained results (Table 1) revealed that the total lipids are affected at the studied drains (Sites I), then elevated again by getting far away from the pollution source (Sites II). Qus, Com Ombo and Etsa are from the agricultural drains which collecting huge amounts of mixed pollutants as nitrate pesticides, Phosphate, Bacteria (from waste water irrigation). Soltan (1995) reported that Kima drain industrial wastewaters exhibits high concentrations of dissolved salts (Ca, Mg, Cl-1, SO4-2, CO3-2, NO2- and NO3-), particularly close to where the waste of the Kima factory enters causing severe pollution, but decrease substantially near the end of the Kima drain due to dilution factor, aeration, sedimentation, oxidation reduction and biochemical effects. Anantharaj *et al.,* (2011) reported that chemical pollution as high concentration of heavy metals could affect on diatoms by reducing its growth (in terms of chlorophyll content) and biochemical compositions (carbohydrate, lipid and protein). also, Okamoto *et al.,* (2001) mentioned that heavy metals are able to induce oxidative stress in chloroplasts of the unicellular alga Gonyaulax, particularly under acute conditions in addition to oxidative damage to proteins and lipids occurred in cells.

Regarding to the total protein the results indicated that proteins decreased at Sites I (Kima, Qus and Etsa) then increased at Site II of the same drains, which may be referred to the impact of these discharges on the quality of the Nile water is only locally significant due to the high self-purification capacity of the Nile water (El Sheekh, 2009). It has been shown that the presence of pollutants can induce oxidative and nitrosative stress and therefore, since algae has important antioxidant system, they can be used as powerful biomarker tools for pollution exposure (Pinto *et al.,* 2003). As mention before the community composition of phytoplankton in River Nile was dominated by diatoms, epilithic diatom assemblages were used to evaluate water quality in the Karasu River basin in Turkey, which was polluted by industrial, agricultural, and urban wastes (Gurbuz and Kivrak, 2002). Fishar *et al.,* (2006) reported that organic effluent from Etsa Drain of River Nile discharging 23750 m3/h of untreated sewage and agriculture effluents from Minia Governorate which affect on aquatic fauna.

Data revealed that the minimum yield for carbohydrates obtained at Sites I then increased again at Site II of the same drains. El-Hawamdia chemical industry and Com Ombo, Qus and El-Hawamdia sugar industry are from the major sugarcane and starch industries which are among the major producers of polluting agro-industrial which affecting River Nile phytoplankton and caused inhibition in its growth and photosynthesis (Franqueira *et al.,* 2000; Ezzat *et al.,* 2002; Sabae, 2004). Abd El-Hady (2008) reported that the phytoplankton biochemical composition (chlorophyll a, lipids, proteins and carbohydrates) in Lake Manzala were inhibited due to the effect of Hadous, Bahr El-Bakar Drains and El-Matariya Pumping station, these wastewater contained high concentrations of organic matter, nutrients, minimum oxygen content, heavy metals and other toxic compounds (Sobhy, 2006). Thus, the pollutants affect the biochemical composition of phytoplankton in this study which showed its reliable biomarker of specific water quality problems.

Phytoplankton biochemical contents to chlorophyll a ratio of both Aswan Reservoir and River Nile

The determination of total chlorophyll, especially chlorophyll "a", is one of the most commonly used parameter for the estimation of the algal growth in River Nile (Shehata *et al.,* 2008; Sobhy, 2008).

The ratio of total biochemical contents to chlorophyll a at Aswan Reservoir and River Nile confirmed our results that winter was the optimum seasons for proteins. Also winter was the optimum season for the ratio of lipid parameters to chlorophyll a at the selected River Nile sites, while at Aswan Reservoir this ratio was the maximum in summer (Fig. 8, A and B). Shaaban *et al.,* (2011) reported that the total chlorophyll contents of the identified algae of Rosetta Branch of River Nile reached their maximum peaks during summer 2007 and there was a positive relation observed between the fluctuations of total chlorophyll contents of the phytoplankton and those of total number of individuals at all investigated sites of Rosetta Branch. On contrary the maximum carbohydrates to chlorophyll a ratio was obtained in autumn at the same locations.

Conclusion and recommendations

Phytoplankton biochemical structure may be affected directly or indirectly by discharge of pollutants in River Nile which may be useful in monitoring the presence of toxic substances for short or long-term changes in water quality. In order to address the problem of the pollution of River Nile, it is strongly recommended that attempts must be made in a holistic manner; the problem of river pollution is not limited to one institution, one activity or limited to a specific time period, it is multidimensional and interventions, to address the problem we should take in consideration long-term and short-term interventions, the protection of water against pollution can be achieved better through controlling of pollution at the source. This study in part will serve as an information tool to enable government have an appreciation of the fact that River Nile is polluted at some of its drains and has negative effects on the phytoplankton composition.

Table 1. Changes in phytoplankton biochemical contents (lipids, proteins and carbohydrates) at some drains of River Nile.

			Lipids (mg/l)			
Drains	Distance from Aswan High Dam (km)	Site code	Spring (2008)	Summer (2008)	Autumn (2008)	Winter (2009)
Kima	25 Km from AHD	I	5.4	12.6	12	8.8
		II	5.8	18.4	8.8	13.4
Com Ombo	51 Km from AHD	I	2.6	8.8	6.8	8.8
		II	5.8	3.6	8.4	14.4
Qus	277 Km from AHD	I	5.4	8.6	10.6	10
		II	4.4	3	11.8	12.6
Etsa	701.15 Km from AHD	I	-	15.6	9	11.2
		II	-	20	7.4	7.4
El-Hawamdia	912 Km from AHD	I	6.4	-	4.4	9.4
		II	7.6	-	6.6	8.8
		Proteins (g/l)				
	Kima	I	2.93	1.19	3.38	4.77
		II	7.94	1.64	3.28	5.61
	Com Ombo	I	2.13	1.08	2.93	6.02
		II	2.11	1.46	2.21	5.22
	Qus	I	4.35	0.57	2.99	6.57
		II	6.5	1.99	3.8	5.44
	Etsa	I	2.4	0.77	3.19	5.22
		II	-	0.79	3.71	7.26
	El-Hawamdia	I	2.6	1.1	2.97	5.19
		II	3.2	0.86	2.78	4.72
		Carbohydrates mg/l				
	Kima	I	92	20	72	4
		II	128	24	72	8
	Com Ombo	I	58	46	28	16
		II	68	24	84	8
	Qus	I	60	28	20	2
		II	24	28	24	12
	Etsa	I	105	36	24	4
		II	-	20	36	8
	El-Hawamdia	I	110	28	32	76
		II	92	32	44	66

Sites I: Polluted water samples which collected at drains. Sites II: Water samples which mixed with clean stream of River Nile.
– Not collected samples. Bold: Parameters increased in biochemical values at Sites II.

Acknowledgement

The author would like to thank members of chemistry laboratory for providing the data of some chemical parameters. The author is also grateful to Dr. Emad H. Sobhy for his help in this work and to Dr. Nehad Khalifa for revising the manuscript.

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