RESPONSE OF MICRO ALGAE TO WATER TREATMENT OPERATION

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Abstract

Algal population of Nile River water is mainly composed of diatoms, green and blue-green algae (cyanobacteria). Percentage composition of algal species was in order diatoms > green algae > cyanobacteria. The conventional water treatment operations lead to the average removal of algae in the ratio of 92 %, 87%, and 77% for diatoms, green and cyanobacteria, respectively. Algal composition of the treated water was subjected to a wide variation after sedimentation and sand filtration. A relative increase in the percentage composition of green algae and cyanobacteria was recorded. Change in algal composition after water treatment operations reflects the wide variation in algal structure and their community.

Key words: Fresh water algae - Harmful algae - water treatment operations.

Introduction

Microalgae of fresh water recourses pose several problems, which affect the quality of drinking water. Algae are negatively charged bio-particles, which interact with the positively charged coagulant and contribute to the coagulant demand (Bernhardt and Clasen, 1991). Meanwhile, their extra–cellular organic matter can adsorb to particles causing a stabilizing effect (Bernhardt *et al.*, 1985).

Algae can affect the rate of sand filtration. Larger algae can form a mat on the sand filters, while small, motile algae can penetrate the filters leading to shortened filter runs and increased use of backwash water. The cylinder type diatoms such as *Nitzschia* and *Synedra* are well known as algae causing filter clogging in rapid sand filtration systems. The settling velocity is related to the physiological condition of algae (Konno, 1993).

Tastes and odor arise from metabolic products of algae as well as the decay of dead cells. (Mallevialle and Suffet, 1987). Cyanobacteria are accused for excretion of neuro-and hepato-toxins (Yoo *et al*., 1995). In addition, algae and their metabolites are precursors for disinfection byproducts, which are carcinogenic compounds (El-Dib and Rizka, 1994; Graham *et al*., 1998; Plummer and Edzward, 2001). The response of algae to treatment operations is affected by variations in shape, morphology and mobility that make their removal more difficult than the removal of inorganic particulates (Bernhardt and Clasen, 1991; Steynberg *et al*., 1996; Plummer and Edzwald, 2002)

(ISSN: 1110-8649)

The present study was run to evaluate the efficiency of conventional water treatment in algal removal and the change in algal population during the treatment operations.

Materials and Methods

Raw water was derived from Nile River at Banha City, in the delta region, 50 Km to the North of Cairo. Water samples were collected from the inlet of Banha water works as well as from the outlet of the sedimentation tanks and after the sand filters. The raw water was subjected to the conventional treatment operations namely, screening, prechlorination (4mg Cl/L) coagulation-flocculation using 40 mg/L alum, sedimentation (2hrs retention time), rapid sand–filtration and finally postchlorination (2 mg Cl/L)

Water samples were collected monthly from autumn 2004, up to summer 2005 to monitor the seasonal changes in the water quality, algal count and algal population. Physico-chemical parameters investigated were: pH, turbidity, electrical conductivity, nitrite, ammonia and phosphate, which were determined according to (APHA, 1998). Nitrate was analyzed according to (DEV, 1984), also total organic carbon (TOC) was measured using a PHENOX TOC analyzer. Algae in water samples were measured by the Sedgwick–Rafter methods (APHA, 1965). Algal counts and their identification were performed according to Starmach, 1966; Streble and Krauter 1978; Palmer 1980.

Results and Discussion

Physico-chemical characteristics of the raw and treated water samples are given in Table (1). The mean value of the parameters investigated for both the raw and treated water revealed some variation during various seasons. pH values were almost in the alkaline range and turbidity of raw water ranged between 5.4 NTU in autumn and 10.7 NTU in winter. Addition of alum to the raw water led to a slight increase in electric conductivity values of treated water. Nitrite and ammonia concentrations were almost zero; nitrate and phosphate levels were extremely low. Values of (TOC) were relatively high in autumn and summer.

Major algal groups in Nile River water were represented by diatoms, green algae and cyanobacteria. Maximum algal counts were reported during winter (10678 organisms/mL) and spring (8220 organisms/mL). Diatoms represented the major percent of algal community covering the range of 82.9% to 86.9%. Green algae amounted from 9 to 11 % of the total algal count whereas cyanobacteria were represented by 4.4 to 6.5 of the algal count (Table 2). Due to coagulation-flocculation and sedimentation operations, percentage of algal removal ranged between 80% in (spring) and 84% in summer and winter, respectively. Diatoms still represented the major algal group in treated water

Table (1): Annual change in some physico-chemical characteristics of water samples at Banha water works

Parameters	Seasons							
	Autumn 2004		Winter 2005		Spring 2005		Summer 2005	
	Raw	Mean of treated water	Raw	Mean of treated water	Raw	Mean of treated water	Raw	Mean of treated water
pH	8.03	7.81 (0.031)	7.97	7.98 (0.028)	8.28	8.23 (0.035)	8.0	7.65 (0.071)
Turbidity NTU	5.4	1.1 (.35)	10.7	1.5 (0.14)	7.45	1.24 (0.6)	6.1	0.7 (0.42)
Electric conductivity µmhos cm^{-1}	387	395 (0.0)	400	417.5 (3.54)	370	370 (0.0)	340	345 (7.0)
Nitrite NO_2-N mg l^{-1}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrate NO_3-N mg l^{-1}	0.79	0.034 (0.01)	0.13	0.076 (0.016)	0.11	0.065 (0.007)	0.082	.044 (0.012)
Ammonia NH_4-N mg l^{-1}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate PO_4-P mg l^{-1}	0.12	0.0	0.23	0.065 (0.035)	0.15	0.0	0.13	0.0
TOC mg C l^{-1}	11.2	12.1 (0.5)	12.6	13 (0.71)	9.4	9.85 (0.35)	13.85	11.23 (0.4)

Standard deviation in between brackets

Table (2): Algal counts of water samples collected during treatment processes at Banha water works

Algal group	Sampling sites											
	Raw				Sedimentation				Sand filter			
	Autumn 2004	Winter 2005	Spring 2005	Summer 2005	Autumn 2004	Winter 2005	Spring 2005	Summer 2005	Autumn 2004	Winter 2005	Spring 2005	Summer 2005
Total Diatoms	4488	9279	6968	5855	728	1284	1221	797	376	330	243	276
% Composition	82.9	86.9	84.8	83.8	72.3	76.9	76.6	72.6	61.0	67.9	57.4	68.8
% Removal					83.8	86.2	82.5	86.4	91.6	96.4	96.5	95.3
Total green algae	572	933	890	798	200	242	253	204	128	86	81	67
% Composition	10.6	8.7	10.8	11.4	19.8	14.5	15.9	18.6	20.8	17.7	19.1	16.7
% Removal					65.0	74.1	71.6	74.4	77.6	90.8	90.9	91.6
Total cyanobacteria	352	466	362	334	80	143	121	97	112	70	99	58
% Composition	6.5	4.4	4.4	4.8	7.9	8.6	7.5	8.8	18.2	14.4	23.5	14.5
% Removal					77.3	69.3	66.6	71.0	68.2	84.9	72.7	82.6
Total algal count	5412	10678	8220	6987	1008	1669	1595	1098	616	486	423	401
% Removal					81.4	84.4	80.6	84.3	88.6	95.4	94.9	94.3

especially in winter and summer and their removal levels amounted to 86.2% and 86.4%, respectively. After sand filtration, removal of algae was considerably increased and ranged between 88.6% and 95%. Diatoms still represented the highest algal count passing through the sand filters followed by the green and cyanobacteria. According to Mouchet and Bonnely (1995) the removal rate of Nile water algae in the clarified water at Cairo plants was 85% in the absence of chlorine and 99% when prechlorination was carried out in combination with a well adjusted coagulant dose.

Mean of percentage composition of algal species in raw Nile River amounted to 84.6, 10.4, and 5 for diatoms, green algae and cyanobacteria, respectively (Table 3). However, after sedimentation percentage composition of algal species showed marked changes where diatoms represented 74.6%, green algae and cyanobacteria amounted to 17.2% and 8.2% of the total algal counts. After sand filtration percentage composition of algae was further changed where diatoms, green and cyanobacteria amounted to 63.8, 18.6 and 17.6% respectively.
The most dominant algal species in water samples collected after sedimentation and sand filtration are given in Table (4). In case of diatoms, *Diatoma elongatum*, that contribute to filter clogging was almost present in the water together with *Cyclotella comta* especially in autumn and winter samples. However *Melosira granulata* was prevailing in spring and summer.

Table (3): Mean of percentage composition of algae after sedimentation and filtration

Algal group	Source of water		
	Raw water	After sedimentation	After filtration
Diatoms	84.6	74.6	63.8
Green algae	10.4	17.2	18.6
Cyanobacteria	5.0	8.2	17.6

Diatoms were considerably decreased after water treatment operations (Table 2), *Synedra ulna* was almost removed after sand filtration during autumn, spring and summer.The green algae *Scenedesmus quadricauda* and *Staurastrum paradoxum* were found in the raw water and treated samples through out the year. *Closterium acutum*, was responded to the treatment operations during autumn and summer.

The distribution of cyanobacteria revealed that *Merismopedia elegans* was always present after sedimentation and sand filtration. Filtered water was free from *Coelosphaerium kuetzingianum* whereas *Cylindrospermum muscicola*, neuro- toxins alga, was isolated after sedimentation in winter, spring and summer. In addition *Microcystis aeruginosa*, a hepato-toxins alga, was found in water samples after sedimentation in autumn, winter and spring but did not show in the summer samples. Chow *et al*. (1999) and Drikas *et al*. (2001) reported that

Table (4): Most dominant algal species for water samples after sedimentation and sand filtration at Banha water works

Algal Species (Organisms/ml)	Autumn 2004			Winter 2005			Spring 2005			Summer 2005		
	Raw	Sed.	Sand filter	Raw	Sed.	Sand filter	Raw	Sed.	Sand filter	Raw	Sed.	Sand filter
Diatoms												
*Diatoma elongatum**	2640	272	152	3630	506	90	121 0	132	0.0	187 0	411	80
*Melosira granulata**	616	192	96	660	264	50	123 2	275	50	110 0	197	60
*Cyclotella comta**	528	120	64	2398	319	90	361 0	660	150	626	93	30
*Synedra ulna**	330	56	0.0	990	121	30	396	0.0	0.0	359	40	0.0
Green- algae												
Scenedesmus quadricauda	154	64	32	396	66	30	220	88	30	190	40	20
Actinastrum hutzschii	-	-	-	132	33	0.0	-	-	-	60	40	30
Pediastrum simplex	132	32	24	-	-	-	-	-	-	88	0.0	0.0
*Staurastrum paradoxum***	88	24	16	132	44	0.0	110	66	20	86	30	0.0
Closterium acutum	66	0.0	0.0	88	66	40	66	33	20	40	0.0	0.0
Cyanobacteria												
Merismopedia elegans	154	48	88	220	77	60	99	55	40	112	30	20
Co. kuetzingianum	16	0.0	0.0	66	22	0.0	55	0.0	0.0	44	0.0	0.0
*Cy. muscicola***•	-	-	-	88	22	0.0	55	11	0.0	56	40	20
Oscillatoria limnetica	66	16	0.0	-	-	-	-	-	-	30	0.0	0.0
Microcystis aeruginosa¤	88	16	0.0	44	11	0.0	110	44	30	-	-	-

* Filter and screen clogging algae.
• Algae cause neuro-toxins.
** Taste and odor algae.
¤ Algae cause hepato-toxins
Co. = ***Coelosphaerium***
Cy. = ***Cylindrospermum***

coagulation and filtration can remove microcystin that is bound within the algal cell, but is effective against dissolved or extracellular toxin.

Micro algae generally show a wide variation in their cell diameter that may affect their behavior during water treatment. Diatoms have cell diameter of about 10µm (*Cocconeis* and *Cyclotella)* whereas others have a diameters of 5-15µm (*Rhizosolenia* sp. and *Skeletonema* sp). Green algae such as *Dictyosphaerium* sp. have a cell diameter of 8-10 µm but others show much smaller values of 2-7 µm (*Ankistrodesmus, Crucigenia and Selenastrum*). Some cyanobacteria exhibit wide variation in their cell diameter (APHA, 1998)

Morphological characteristics of algae might have a role in their behavior during water treatment operations and their ability to adhere, settle and/or pass through the sand filters (Konno, 1993 and Pieterse and Cloot 1997). The observed increase in the percentage composition of green algae and cyanobacteria after sedimentation and sand filtration suggests that several species of green and cyanobacteria have cell diameter less than 4 µm.

Ali, (2003), studied the size structure of fresh water phytoplankton in River Nile. The mean biovolume of green algae represented high values from total phytoplankton biovolume that ranged between 51% and 61%. Other phytoplankton groups revealed high fluctuation in its biovolume during different seasons and different sampling site.

Conclusion:

Algal population of Nile River water is mainly composed of diatoms, green and cyanobacteria. Diatoms represent the most dominant algal group followed by green and cyanobacteria. The average removal levels of algae by conventional water treatment operations were 92%, 87% and 77% for diatoms, green and cyanobacteria, respectively. However, diatoms still represent the highest algal count passing through the sand filters .The neuro-toxin alga *Cylindrospermum muscicola* was isolated after sedimentation in winter, spring and summer. The hepato-toxin alga *Microcystis aeruginosa* was found in water sample after sedimentation in autumn, winter and spring. Variation in the response of algae to water treatment operation may be attributed to the morphological characteristics of algae, their cell diameter, cell volume and/or their electric charge.

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استجابة طحالب المياة العذبة لعمليات تنقية المياة

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قسم بحوث تلوث المياة –المركز القومى للبحوث- ش التحرير- الدقى.

تتناول هذه الدراسة عد وتصنيف أنواع الطحالب والمشكلات التى قد تسببها فى عمليات تنقية المياة ونوعية مياة الشرب وذلك من خلال تتبع تأثير عمليات التنقية.

وقد احتوت مياة نهر النيل على ثلاث مجموعات من الطحالب وهى الدياتومات والطحالب الخضراء والطحالب الخضراء المزرقة (السيانوبكتريا) وكانت أعداد الطحالب تِبعاً للترتيب التالى:-
الدياتومات > الطحالب الخضراء > السيانوبكتريا.

وتدل النتائج على أن معدل إزالة الطحالب بمجموعاتها خلال عمليات التنقية التقليدية يكون بالنسب التالية : 92 % للدياتومات , 87 % للطحالب الخضراء , 77 % للسيانوبكتريا.
ونتيجة لعمليات التنقية أختلفت نسبة توزيع أنواع الطحالب تِبعاً لإختلاف أستجابة أنواعها لعمليات الترسيب والترشيح مما يؤدى الى تغيُر كبير فى العشائر الطُحلبية.