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EFFICIENCY OF ALUM AND LIME-ALUM TREATMENTS FOR REMOVING TOXIC AND NONTOXIC PHYTOPLANKTON FROM THE NILE RIVER WATER: LABORATORY STUDY

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Abstract

No phytoplankton should be present in treated drinking water because of their production for bad smell and toxins that may pose hazards to animals and human upon consuming this water. This study describes the efficiency of alum and lime-alum treatments for removing phytoplankton from the Nile river water used as a source of drinking water in Egypt. The results showed that alum could not precipitate all phosphate nor coagulate waterblooms-forming cyanobacteria present in the water sample. Conversely, lime-alum treatment precipitated much more phosphate than alum did, and coagulated all phytoplankton present in the water samples including those could not be coagulated by alum. Furthermore, lime-alum treatment did not change the pH of the water during all the experiment period. Hence, it is advisable that lime-alum be used instead of alum during water treatment process in Egypt.

Key words: alum, cyanobacteria , lime-alum, microcystins, phytoplankton, removal

Introduction

Eutrophication in lakes, occurs as a consequence of high external inputs of nutrients, particularly phosphorus (Schindler 1984). Under these conditions, cyanobacteria grow intensively due to their capacity to take up nutrients at low levels (Perkis 1994).

Photosynthetic organisms, including algae and cyanobacteria, release naturally particulate organic materials into the aquatic systems during their active growth. The rate of their release were elevated during the decaying phase of cells (Baines and Pace 1991). Cyanobacteria produce two main types of toxins with alkaloid and protein nature. The cyanotoxins are classified into into neurotoxins and hepatotoxins according to their mode of action (Carmichael 1988;1992). Hepatotoxins, especially microcystins are commonly encountered cyanobacterial toxins, and have caused most of the animal poisoning (Carmichael, 1992; Ressom *et al.* 1994) as well as human beings (Jochimsen *et al.*1998). The release of microcystins by cyanobacteria in drinking water reservoirs has been raised to health concerns (Falconer 1993; Carmichael and Falconer 1993) and increased the attention towards the removal of cyanobacteria and their toxins from the sources of drinking water (Lam and Prepas, 1997; Mohamed *et al.*1999).

Chemicals used to control the growth of phytoplankton such as copper sulphate ($CuSO_4$), Reglone-a, Simazine, potassium permanganate ($KMnO_4$) and chlorine, have a good efficiency to remove phytoplankton by disrupting cell functions,inhibiting cell wall synthesis, photosynthesis and suppersing enzyme activity. Lam *et al.* (1995) reported that both alum and lime remove phosphorus from the water as well as they coagulate the cells with special references to alum. However, the addition of lime may

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decrease the abundance of zooplankton by increasing the pH in lakes above 10 (Hansen *et al.* 1991) and likely affect other organisms such as benthic invertebrates.

Although no poisoning incidents due to cyanobacterial toxins have been reported in Egypt, a recent study revealed the presence of toxic cyanobacteria in some Egyptian freshwater bodies (e.g. The Nile river and irrigation canals) which are usually used as sources of drinking water (Mohamed 1998). Since water treatment with alum and lime changes the pH of the treated water, the achievement of such treatments differs from one kind of water to another depending on the buffering capacity of the water (Zhang and Prepas 1996

The aim of this study is to evaluate the efficiency of alum and lime-alum for coagulation and sedimentation of phytoplankton in the Nile River without hazards to the water, which usually used as a source of drinking water in Egypt.

Materials and Methods

Sample collection of phytoplankton: Phytoplankton samples were collected during May 1999 with a 25-µm mesh net from the Nile river water at the tube of water treatment station at Sohag city, Upper Egypt. An aliquot of sample was preserved in Lugol,s solution for counting, while another one was used for the following analysis.

a- Determination of phytoplankton biomass, toxicity and composition: Phytoplankton biomass was determined by filtering one liter of the water sample throughGF/C glass-fiber filters (0.45µm). The filter papers with cells were dried for 24h at 100 °C and then weighed. The toxicity of phytoplankton was estimated by *Artemia salina* test according to Kiviranta *et al.* (1991) and by Enzyme linked immunosorbent assay (ELISA) using polyclonal antibody according to the method of An and Carmichael (1994). Phytoplankton composition was investigated by light microscope and counted using haemocytometr. The filamentous and colonial algae were counted as filaments and colonies, respectively. The algae were identified according to Presccot (1978).

b- Treatment experiments: Nine 3L-glass jars were used for this purpose. To each jar, One liter of phytoplankton collected by net, was placed. Three jars were used for alum treatment and dosed with an appropriate amount of alum [$Al_2(SO_4)_3$. $14H_2O$] (75 mg/L), the quantity that keeps the pH of the water above 6. Another three jars were used for lime-alum treatment and dosed with 100 mg/L lime $Ca(OH)_2$, the quantity that is sufficient to precipitate all phytoplankton. To keep the pH of the water below 10, or rather at the same pH of the river water, these jars were dosed again with 75 mg/L of alum. The remaining jars were not treated with chemicals and used as a control. Both treated and control jars were placed for four weeks in controlled chamber at 30±2°C, and illuminated with fluorescent light at 24 µmole m^{-2} s^{-1} in a 16:8 light: dark cycle.

Samples of the clear water were collected carefully and weekly from each jar with a peristaltic pump for chl.a, microcystin and orthophosphate analyses. At the same time, one ml of the precipitate of the two treated jars was taken for determination of chl.a content. Chl.a content was determined according to Talling & Driver (1963). The cells were ground with 90% methanol to ensure the dissociation of the lime layer formed around the cells. Microcystin concentration was determined by ELISA. Orthophosphate content was determined according to Dewis & Freitas (1970).

To estimate precipitate-to-water phytoplankton recruitment in response to alum and lime-alum treatments, 100 ml of the clear water were pippeted carefully and daily for 15 days. The phytoplankton present in the pipetted water after identification, were counted by haemo-cytometer.

Results

Phytoplankton sample used in this study, contained representative species of cyanobacteria, chlorophyta and diatoms (Table 1).

Table 1. List and number of phytoplankton species present in the Nile river water used in alum and lime-alum treatments.

Species	Number/ ml
Cyanobacteria	
Aphanizomenon flos-aquae Ralf	^{f}50
Chrooccocus minor Naegeli	^{c}1500
Gomphosphaeria lacustris Chodat	^{co}100
Merismopedia incerta Lemmermann	^{co}400
Microcystis aeruginosa Kuetz	^{co}200
Oscillatoria agardhii Gomont	^{f}50
Oscillatoria limnetica Lemmermann	^{f}50
Chlorophyta	
Ankistrodesmus falcatus Ralfs	^{c}5000
Chlorella ellipsoidea Gerneck	^{c}9000
Dictyosphaerium pulchellum Wood	^{co}100
Pediastrum simplex Lemmermann	^{co}100
Scenedesmus obliquus Kuetzing	^{c}8000
Diatoms	
Fragilaria sp..	^{co}3000
Melosira sp.	^{co}5000
Synedra sp.	^{c}500

c= cell , co = colony , f = filament , O = organism

This sample was found to be toxic as determined by *Artemia salina* and ELISA (Table 2).

Table 2. Biomass and toxicity of phytoplankton sample used in the present study.

Dry weight	223 mg/L
Toxicity by ELISA	128µg/g dry weight
Toxicity by *Artemia* (LC_{50})	60 mg/ml

Chl.a content of alum-treated cells and control showed remarkable change during all the experiment period. Chl.a content of lime-alum-coagulated cells did not significantly change after one week allover the experiment period (Fig.1).

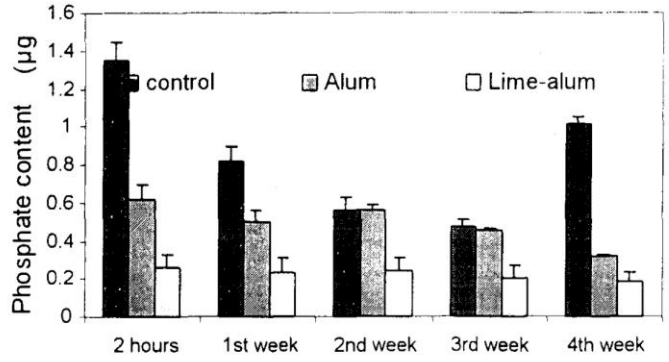

Fig.1: Changes in chl.a content of the cells under the conditions of Control, and alum and lime-alum treatments

Both alum and lime-alum treatments, affected markedly the phosphate level of the river water used in this experiment (Fig.2). However, lime-alum precipitated much more phosphate than alum did.

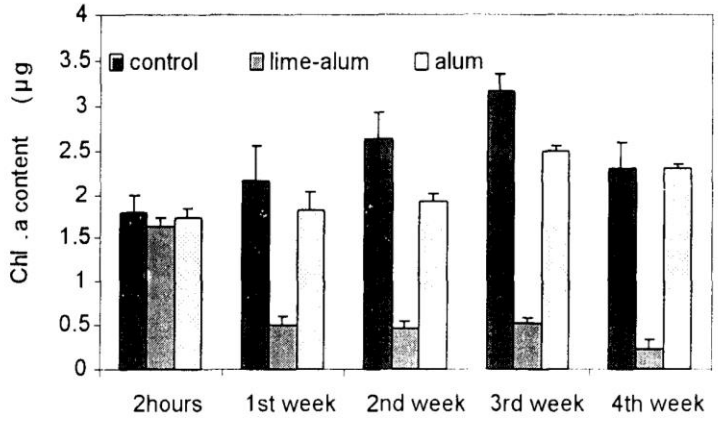

Fig.2: Effect of alum and lime-alum treatments on the concentration of orthophosphate of the water sample used in the present study.

Meanwhile, phosphate level in the control jar decreased gradually until the third week of the experiment period, and increased afterwards. pH did not change significantly in either control or treated jars during all the experiment period (Table 3).

Table 3. pH changes in control and treated jars during all the experiment period

Treatment	2 hours	1st week	2nd week	3rd week	4th week
Control	8.22	8.18	8.14	8.3	8.48
Alum	6.5	8.00	8.1	8.00	8.00
Lime-alum	7.92	8.22	7.9	7.85	7.62

It has been shown that cyanobacterial species *Aphanizomenon, Merismopedia* and *Microcystis* started to migrate after one day from the precipitate formed by alum to the clear water (Fig.3a, b &c). In contrast, no species released from the precipitate formed by lime-alum treatment. Thus, the water in this jar remained clear during all the experiment period, thereby no data were shown. Chl.a content and microcystin level were found to be undetectable in the clear water of either control or treated jars (data not shown).

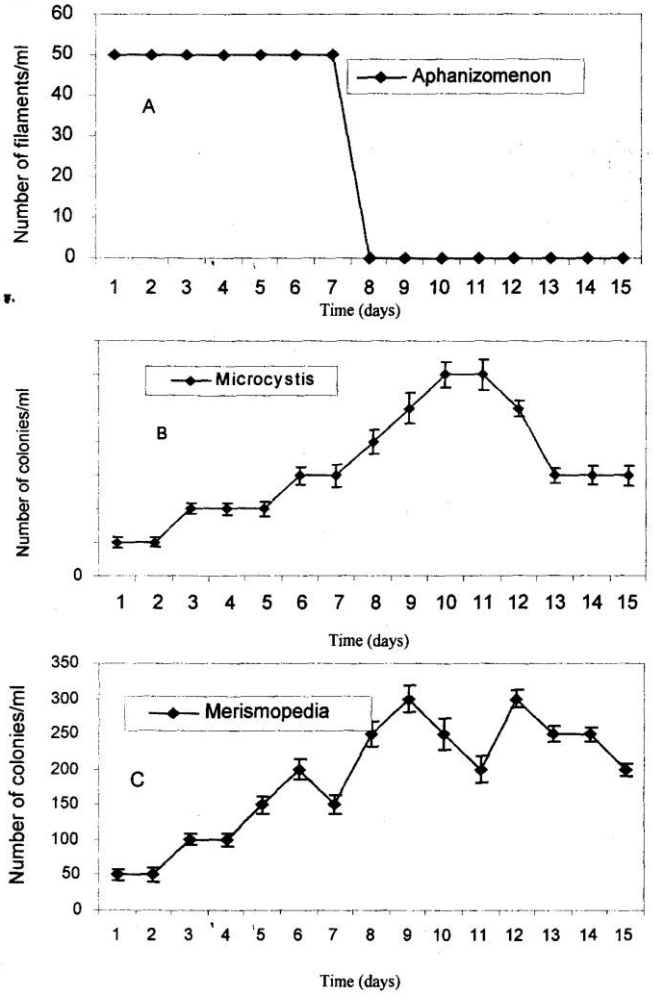

Fig. 3: Migration of *Aphanizomenon* (A), *Microcystis* (B), and *Merismopedia* (C) into the clear water under alum treatment conditions

Discussion

Chemicals commonly used in water treatment processes and surface water management can be classified on the basis of their effect on cyanobacteria (Lam. *et al.* 1995). Type 1 chemicals disrupt cell functions and induce cell lysis; they include copper sulphate (Kenefick *et al.* 1993), Ragelone A, chlorine, and potassium permanganate (Lam. *et al.* 1995). Type 2 chemicals precipitate phytoplankton and leave cells essentially intact; they include lime ($Ca(OH)_2$); (Kennewick *et al.* 1993; Lam *et al.* 1995) and alum ($Al_2(SO4)_3$. $14H_2O$; Lam *et al.*, 1995). Type 2 chemicals have been recommended for treating toxic phytoplankton blooms because they induce minimal release of toxins into the surrounding water (Lam. *et al.*1995). In the present study, alum treatment did not decrease the pH of the water below 6 (the pH below which aluminum becomes increasing soluble and will kill aquatic organisms). However, it could not precipitate all the phosphate in the water sample nor coagulate waterblooms forming cyanobacteria.

During the water treatment with lime, the pH should be maintained below 10 to avoid pH shock to aquatic life (Murphy and Prepas 1990). In the present investigation, the application of lime-alum treatment solved this problem and kept the pH of the water below 8, the value of the natural pH of the Egyptian freshwaters.

The unchanging in chl.a content of lime-alum-coagulated cells in the present study may be attributed to chemicals coatings formed around the cells that prevented the growth (chl.a) and the release of intracellular substances (e.g. pigments, toxins, etc.). In this respect, Lam *et al.* (1995) showed that *Microcystis* cells that were treated with lime or alum appeared to have a chemical coating on the cell surface. They also reported that microcystin-LR would persist and decay inside the lime or alum-coagulated *Microcystis* cells before being released into the surrounding water. No phytoplankton should be present in treated drinking water because of their production for bad smell and toxins that definitely will pose hazards to animals and human being upon consuming this water. Thus conventional water treatment practices such as flocculation, sedimentation and chemical coagulation (by $Al_2(SO4)_3$) together with sand filtration and chlorination, are usually performed in many countries including Egypt. However, each of the above treatments has its own drawbacks.

Concerning this study, lime-alum treatment should be used instead of alum for safe removal of phtoplankton during water treatment processes, and likely to control the growth of phytoplankton in the Egyptian freshwaters.

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كفاءة الشب ومخلوط من الشب و الحجر الجيري لإزالة الطحالب الهائمة السامة و غير السامة من مياه نهر النيل: دراسة معملية

زكريا عطيه محمد

قسم النبات كلية العلوم بسوهاج جامعة جنوب الوادي سوهاج ٨٢٥٢٤ مصر

يجب أن ألا يكون هناك طحالب هائمة موجودة في مياه الشرب المعالجة، نظرا لإنتاج هذه الكائنات لرائحة كريهة و سموم يمكن أن تسبب مخاطر لكل من الإنسان و الحيوان عند استخدام هذه المياه. تصف هذه الدراسة كفاءة الشب و مخلوط من الشب و الحجر الجيري لإزالة هذه الهائمات من مياه نهر النيل. وضحت النتائج أن مادة الشب بمفردها لاترسب كل الفوسفات ولا تجلط السيانوبكتريا (الطحالب الخضراء المزرقة) التي لها المقدرة علي تكوين ازدهارات مائية. و علي النقيض، فان المعالجة بمخلوط من مادتي الشب و الحجر الجيري رسبت كمية اكبر من مثيلتها مع الشب بمفرده، فضلا علي انه جلط كل الهائمات الطحلبية بما فيه السيانوبكتريا التي لم يستطع الشب تجليطها. و الأبعد من ذلك، لم يغير مخلوط الشب و الحجر الجيري من الرقم الهيدروجيني للمياه طوال مدة التجربة. و في النهاية توصي الدراسة باستخدام مخلوط من الشب و الحجر الجيري بدلا من الشب بمفرده أثناء عملية معالجة مياه الشرب للتخلص من الهائمات الطحلبية بكفاءة.