Application of Multi-level Electromagnetic Fields for Removal of Algae Bloom (*Euglena sanguinea*)

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Abstract

The objective of this research was to study a technique for removal of algae bloom (*Euglena sanguinea*) by using multi-level electromagnetic fields (MLEMF). With this technique, an electrical power was changed to be an electric field by an electronic control. An electron was transferred by electric field. The experiment was stimulated in a 10 L lab scale. The voltage of system could be adjustable from 0 to 60 Vac and frequency was 10 kHz. The research aimed to study the physical, biological, and chemical properties of water. After treating by MLEMF, it was found that the membrane crashed and collapsed even the organs deformed. Moreover, treatment efficiencies of SS, turbidity, COD, TN and TP represented to 89%, 96%, 73%, 67%, and 94%, respectively. The reaction of algae bloom removal was related to concentration of algae according to time followed by the first order reaction with a rate constant of 0.0004 s^{-1}. This technique can be applied in the production of new water supply process. The advantage of this technique is no chemical involved. MLEMF technology proposes clean water without chemical color residues.

Key words: Multi-level electromagnetic fields (MLEMF), algae bloom, *Euglena sanguinea*, electric current, voltage

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1. Introduction

Algae bloom can cause a serious problem to surface water which is a water source for drinking water production due to their rapid growth. This also affects many water sources. Algae bloom in water source causes a deterioration of water in waterworks and requires high chemical consumption for removal [1]. Most of *Euglena sanguinea* (*E. sanguinea*) found in freshwater become to be an algae bloom that causes water pollution. *E. sanguinea* generates the ichthyotoxin or the euglenophycin which affects the economic aquatic animal [2]. Algae removal from water treatment process is difficult because of their small size and low specific gravity [3-4]. Scientists have already tried several ways to eliminate algae such as using a sedimentation process and filter with substance typed peroxidant such as ozone, chlorine dioxide and permanganate, sedimentation process with ultrasonic irradiation and cray's techniques [4-7] but each method is complicated and some technique may cause pollutions [1]. Therefore, many scientists try to research for a new technique. Multi-level electromagnetic field (MLEMF) is an interesting method. With this technique, an electrical power was changed to be an electric field by an electronic control. An electron is transferred by electric field. It can purely eliminate algae with less complicated process, less retention time, low cost and without of chemical consumption. This research purposes to study an efficiency of algae bloom removal by using the new technology, multi-level electromagnetic fields. This technique can be applied in the production of new water supply and drinking water process.

2. Materials and Methods

2.1 Material
Sample of *E. sanguinea* solution was collected from Klong (canal) 5 in Phathumtanee, Thailand. The color water sample was rarely red. The concentration of suspended solid was equal to 108 mg/L.

2.2 Method
The water sample containing algae (*E. sanguinea*) was treated in a 10-litre (lab scale) vessel by multi-level electromagnetic fields (MLEMF) as shown in Fig.1. MLEMF controller discharged electrical voltage that could be adjusted a voltage level from 0 to 60 Vac and low frequency 10 kHz was passed through MLEMF coil. An electrical power fed to a system was changed to an electric field by a unit in V/m. The electronic system an electron was transferred from solenoid coil passed through water containing *E. sanguinea*. It caused molecule of water and *E. sanguinea* ionized to small potential. *E. sanguinea* was deformed and agglomerated and then precipitated out from the water.

2.3 Analysis methods
The amounts of algae were examined by using light microscope and scanning electron microscope (SEM) with Gang's method [8].

Suspended solids (SS), turbidity (NTU), chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP) were analyzed before and after treatment with MLEMF using standard methods [9].
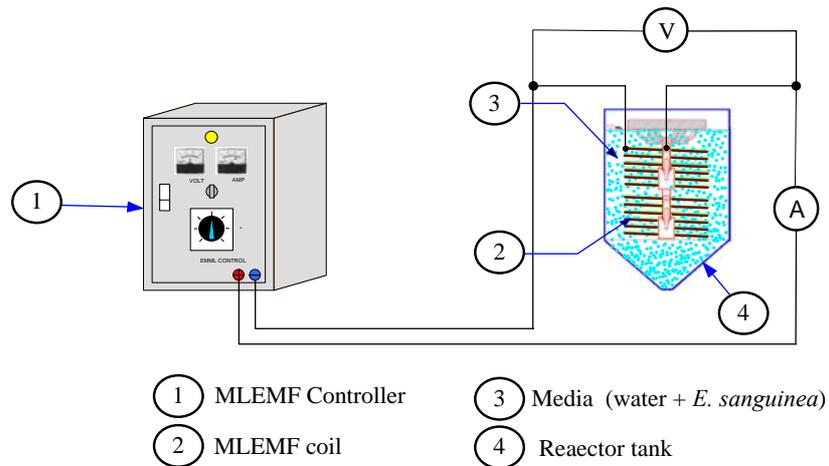
1	MLEMF Controller	3	Media (water + *E. sanguinea*)
2	MLEMF coil	4	Reaector tank

Figure 1 Schematic diagram of the experimental procedure

3. Results and Discussion

3.1 Efficiency of MLEMF process

It was found that water samples before treating by MLEMF were red. Some small sediment was mixed up and a lot of algae with a little bit smelly adhered at the reactor. After treating by MLEMF for 40 minutes it was found that there was a separation of layer among group of algae floating up to water surface and color of the water sample was changed to clear color. The forms of *E. sanguinea* before and after treating by MLEMF were different as shown in Figure 2. Before treating by MLEMF, cell had been moving and outer membrane orderly lined up with perfect organs. Meanwhile, after treating by MLEMF, the movement stopped, the outer membrane crashed and collapsed even the organs deformed.
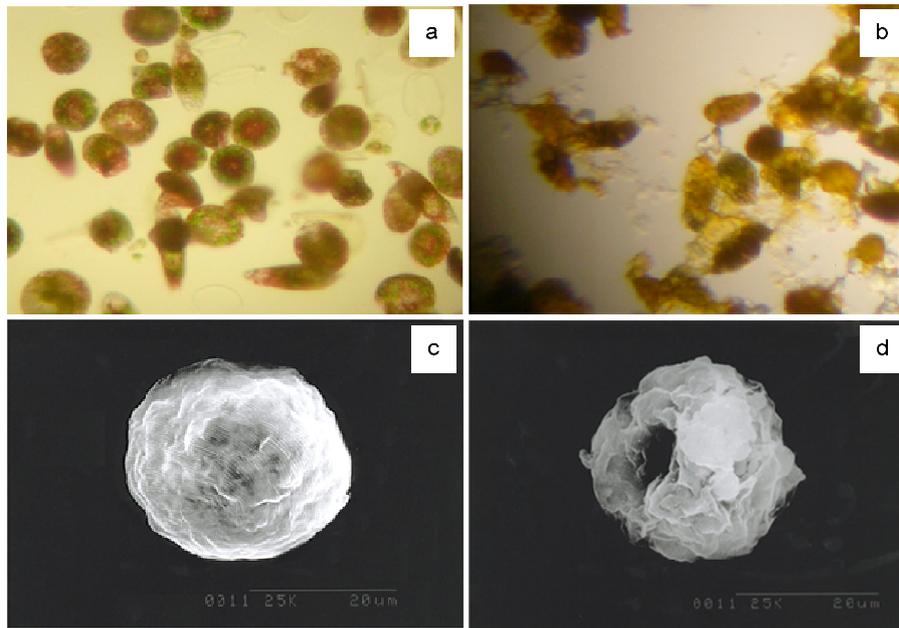
Figure 2 Upper; Microbes from light microscope, (a) before treatment with MLEMF, (b) after treatment with MLEMF, Lower; SEM micrographs of cell (*Euglena sanguinea.*) surface morphology. (c) before treatment, (d) after treatment with MLEMF

Table 1 presents the results of chemical properties of water sample before treating by MLEMF. It was found that water sample consisted of organics, nitrogen and phosphorus in high quantity [8]. Table 2 presents that the water quality after treatment with MLEMF had organics, nitrogen and phosphorus properties less than before treatment. In addition, the efficiency of MLEMF in removal of SS, Turbidity, COD, TN, and TP represented to 89%, 96%, 73%, 64%, and 94%, respectively.

Table 1 Water qualities before MLEMF treatment

Parameter	Turbidity	SS	COD	TN	TP
No. of sample	20.00	20.00	20.00	20.00	20.00
unit	NTU	mg/l	mg/l	mg/l	mg/l
Mean value	21.53	108.00	54.30	9.70	1.84
Minimum	20.54	102.00	51.00	2.00	0.80
Maximum	23.20	112.60	57.00	15.00	2.50
Standrad deviation	1.22	2.44	1.69	3.13	0.47

Table 2 Water qualities after MLEMF treatment

Parameter	Turbidity	SS	COD	TN	TP
No. of sample	20.00	20.00	20.00	20.00	20.00
unit	NTU	mg/l	mg/l	mg/l	mg/l
Mean value	2.29	3.33	4.21	3.16	0.10
Minimum	1.90	2.00	3.00	2.00	0.05
Maximum	2.50	4.00	6.00	4.00	0.12
Standrad deviation	0.15	0.66	1.24	0.73	0.02

3.2 MLEMF kinetic

The results of MLEMF for removal of algae bloom after treating by multi-level electromagnetic fields showed that concentration of algae reduced according to time. In this research, rate constant was calculated from the relation between reactant concentration and time. The obtained reaction rate constant (k) at 29ºC equaled to 0.0004 s^{-1} as shown in Fig. 3. The occurring reaction was first-order reaction and reaction rate depended on the concentration of reactant as presented in equation 1.

$$a \xrightarrow{\quad k, P_{MLEMF} \quad} b \qquad\qquad (1)$$

Where a is the reactant and b is the product. Reaction ratio (r) is the decreasing proportion to reactant a by time, da is the derivation of concentration (a), dt is derivation of time and k is rate of constant.
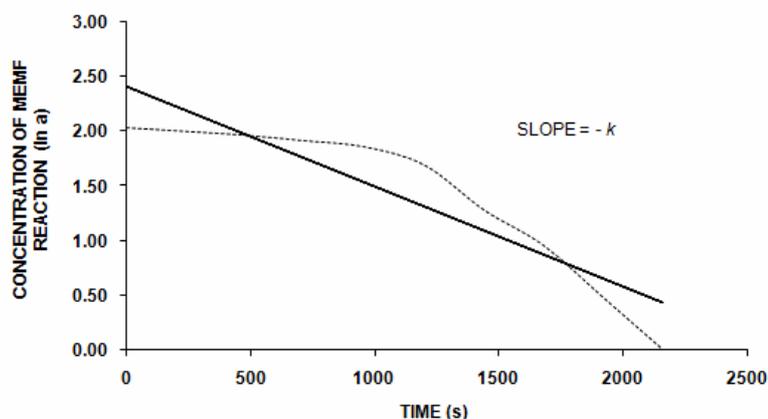

Figure 3 The reaction of MLEMF and rate of constant at 29 ºC

$$r = -\frac{da}{dt} = k[a] \qquad\qquad (2)$$

Then the equation could be rearranged as follows:

$$-\frac{da}{[a]} = k\,dt \tag{3}$$

Integrating equation (3) yields:

$$\ln[a] = -kt + C \tag{4}$$

Integration C constant could be estimated from limited condition when $t=0$, $[a] = [a_0]$ then replaced into equation (4) to be:

$$\ln[a]_0 = -k(0) + C \tag{5}$$

Where $[a_0]$ is the concentration of reactant at $t = 0$. Hence, integration constant is:

$$C = \ln[a]_0 \tag{6}$$

Replaced equation (6) into equation (4):

$$\frac{\ln[a]}{[a]_0} = -kt \tag{7}$$

Rearranging equation according to Reynolds theory [10], the solution is:

$$[a] = [a]_0 \exp^{(-kt)} \tag{8}$$

According to the density of electric current occurring in chemical system of MLEMF [11-12], it can determine the maximum electric current (I_{max}) in reaction by reaction ratio as follows:

$$I_{max} = n\,F\,r \tag{9}$$

Where n is amount of electron and F is Faraday's constant (9.649×10^4 C/mol). Then replaced equation (2) into equation (9) becomes to be:

$$I_{max} = n\,F\,k\,[a] \tag{10}$$

Then replaced equation (8) into equation (10). Total electric current in the unit of A/L of MLEMF system is:

$$I_{max} = n\,F\,k\,[a]_0 \exp^{(-kt)} \tag{11}$$

Output signal of voltage of MLEMF is in form of sinusoidal as shown in Fig. 4 [13].
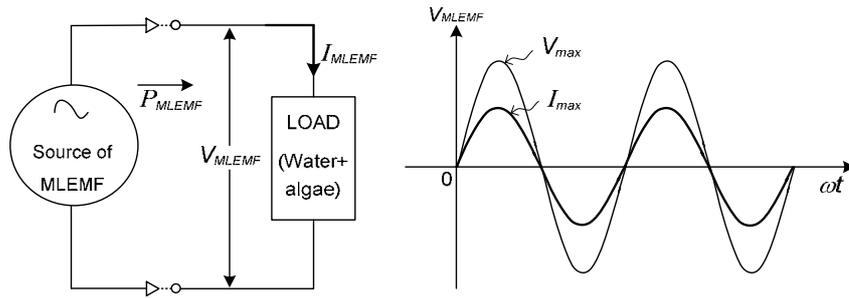
Figure 4 Output signal of voltage of MLEMF system

Output signal of voltage and electric current of MLEMF could be defined by equations (12) and (13).

$$V_{MLEMF} = V_{max} \sin(\omega t + \theta) \qquad (12)$$

$$I_{MLEMF} = I_{max} \sin \omega t \qquad (13)$$

Where θ is the phase angle. The power delivered to the load of Fig. 4 depending upon the time could be defined by equation (14) [13]:

$$P_{MLEMF} = V_{MLEMF} \ I_{MLEMF} \qquad (14)$$

Replaced equations (12) and (13) into equation (14).

$$V_{MLEMF} = V_{max} I_{max} \sin \omega t \sin(\omega t + \theta) \qquad (15)$$

Trigonometric identities were used, it will find electric power equation that can represent as follows:

$$P_{MLEMF} = V_{max} I_{max} \cos \theta (1 - \cos 2\omega t) + V_{max} I_{max} \sin \theta (\sin 2\omega t) \qquad (16)$$

When V_{MLEMF} and I_{MLEMF} are in phase, water and algae are resistant load, $\theta = 0°$. Then replaced $\theta = 0°$ into equation (16).

$$\begin{aligned} P_{MLEMF} &= V_{max} I_{max} \cos 0°(1 - \cos 2\omega t) + V_{max} I_{max} \sin 0°(\sin 2\omega t) \\ &= V_{max} I_{max} (1 - \cos 2\omega t) + 0 \end{aligned} \qquad (17)$$

$$P_{MLEMF} = V_{max} I_{max} - V_{max} I_{max} \cos 2\omega t \qquad (18)$$

The average power from equation (18) in characteristic of resistant load was calculated from the probation [13]. Therefore, P_{MLEMF} is:

$$P_{MLEMF} = V_{max} \, I_{max} \, / \, 2 \tag{19}$$

Where P_{MLEMF} is the electric power of MLEMF in the unit of W/L resulted from replaced equation (11) into equation (19).

$$P_{MLEMF} = n \, k \, F \, V_{max} \, [a]_0 \exp^{(-kt)} / 2 \tag{20}$$

Where a_0 is reactant concentration of the biochemical compositions of algae at $t = 0$ including protein, chlorophyll, carbohydrate, lipid and phosphorus compounds from extraction by concentration testing and mean element formulae [14-15], t is retention time and V_{max} is voltage MLEMF controller.

According to the principle of MLEMF, the researcher tried to develop MLEMF system which could be applied for the removal of algae bloom in open surface water such as pond and lake. Structure and component of MLEMF prototype are shown in Fig. 5.
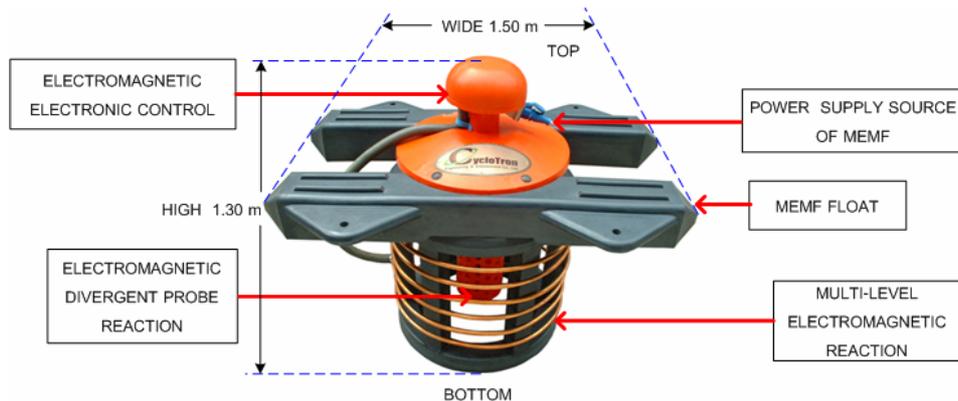

Figure 5 Structure and component of MLEMF machine

Figure 5 shows MLEMF structure which consisted of electromagnetic electronic control. It specified the direction of electromagnetic as multilayer receiving electric energy from power supply of MLEMF. MLEMF float performed to be a buoyancy system to the multi-level electromagnetic fields to float above the water surface and determined the position clear. Electromagnetic divergent probe reaction performed to be an electric particle shooter in form of various frequencies which destroyed some small electromagnetic fields around molecules of colloid and destroyed thin film between water and molecule. So, the molecules of colloid were agglomerated and precipitated. Multilevel electronic reaction performed as a converter to convert the electric energy to the electromagnetic energy inducting the molecules sediment.

4. Conclusions

MLEMF system is a new technology that is developed for removal of algae bloom in surface water. It occupies a principle of multi-level electromagnetic fields. No chemical and biological processes are required and it is easy to operate. It can be applied in the production of new water supply process. MLEMF technology purposes clean water without chemical color residues and it may be useful in troubleshooting of surface water such as pond and lake with algae bloom problem.

5. Acknowledgements

References

[1] Zhang, G., Zhang, P., Wang, B. and Liu, H. **2003**. Ultrasonic frequency effects on the removal of *Microcystis aeruginosa*, *Ultrasonic Sonochemistry*, 13, 446-450.

[2] Zimba, P. V., Rowan, M. and Triemer, R. **2004**. Identification of euglenoid algae that produce ichthyotoxin (s), *Journal of Fish Diseases*, 27, 115-117.

[3] Ma, J. and Liu, W. **2002**. Effectiveness and mechanism of potassium ferrate (VI) preoxidation for algae removal by coagulation, *Water Res*, 36, 871-878.

[4] Petruševski, B., van Breemen A. N. and Alaerts, G. **1996**. Effect of permanganate pretreatment and coagulation with dual coagulants on algae removal in direct filtration, *J. Water Supply Res. Technol. –AQUA*, 45, 316-326.

[5] Steynberg, M. C., Gugleilm, M. M., Geldenhuys, J. C. and Pieterse, A. J. H. **1995**. Chlorine and chlorine dioxide: pre-oxidants used as algocide in potable water plants, *J. Water Supply Res. Technol. – AQUA*, 45, , 162-170.

[6] Zou, H., Pan, G. amd Chen, H. **2006**. Removal of cyanobacterial blooms in Taihu Lake using local soils. II. Effective removal of *Microcystis aeruginosa* using local soils and sediments modified by chitosan, *Environmental Pollution*, 141, 201-205.

[7] Heng, L., Jun, N., Wen-jie, H. and Guibai, L. **2009**. Algae removal by ultrasonic irradiation-coagulation, *Desalination*, 239, 191-197.

[8] Pan, G., Chen H., and Yuan, X. **2005**. Removal of harmful cyanobacterial blooms in Taihu Lake using local soils. III. Factors affecting the removal efficiency and an situ field experiment using chitosan-modified local soils, *Environmental Pollution*, 141, 206-212.

[9] American Health Association, American Water Works Association, Water Environment Federation. **1998**. *Standard methods for the examination of waste water and wastewater*, 20th Ed. Washington DC.

[10] Reynolds, C. S. **1884**. *The ecology of freshwater phytoplankton*: Cambridge University Press, Cambridge, U. K.

[11] www.chimie.unbuc.ro/biblioteca/anale/2002b/127-134.pdf.

[12] Scott, K. **1991**. *Electrochemical reaction engineering*. Academic Press, Toronto.

[13] Robert L. B. **1990**. *Introductory Circuit Analysis*. Sixth ed. Macmillan Publishing Company, New York.

[14] Packamwongsang, K., Nopanakeepong, S. and Pheawbang, P. **2008**. Evaluation of Complex Impedance and Equivalent Circuit of Euglena Sanguinea Ehrenberg with Electromagnetic multi-level. *The 31st Electrical Engineering Conference (EECON-31)*, Nakornnayok, Thailand.

[15] Fraga, F. and Pérez, F. **1990**. Transformaciones entre composición química del fitoplancton. composición elemental yrelación de Redifield, *Sci. Mar*, 54(1), 69-76**.**