ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Algae Disintegration in Raw Water at Semberong Barat Dam Johor Malaysia Using Sonification Wave.

Roslan Omar[ab]*, Zaharah Ibrahim[b], Zailan Zahid[a], Elias Ismail[a], Ikmal Hisham[a], Shahzatul Irwan Omar[a], Siddiq Mustafar[a].

[a]Water Academic Department, SAJ Holdings Sdn. Bhd., Jalan Garuda 80350 Johor Bahru, Malaysia
[b] Faculty of Bioscience and Medical Engineering, University Teknologi Malaysia, Skudai, 81310 Johor Bahru, Johor, Malaysia.

ABSTRACT

Algal bloom and eutrophication pose serious problems to water production from water treatment plants. The toxic that certainly produced from the enzyme secretion by algae also contribute the risk to human health. To control and identify the algal bloom and eutrophication in Sembrong Barat Dam, LG Sonic MPC-Buoy was used. This device uses ultrasonic waves to break down the gas vesicle and cell wall of algae. However, an accurate and reliable mathematical representation for algae disintegration is important to better manage the algal bloom. In this study, the used of Fourier Trigonometry form was fitted. The data were recorded for 14 months, from November 2014 to December 2015. Oscillatoria, actual algae, and chlorophyll-a, has measured using the FlowCAM imaging. Using the equation developed to calculate the sonic wave impact on algae is significant to advance a better understand on the breakdown of the algae cell. The osmosis process occurred once the sonic wave ruptured the cell wall.The derivation of the equation is benefited to determine the energy used to breaking the cell wall or membrane and cytoplasm.

Keywords: Algal bloom, Sembrong Barat Dam, LG Sonic MPC-Buoy, mathematical equation

Corresponding author

INTRODUCTION

The level of phosphate and nitrate nutrients plays a key role in the outbreak and growth of algal blooms. In other words, phosphate and nitrate are the indices that control this process. Land use management of upstream catchment area and implementation of total maximum daily load plans and nutrient load allocation plans (increasing or decreasing the consumption of fertilizers and chemical pesticides in upstream farms) may control eutrophication at the bays [1]. Eutrophication has been one of the major water quality problems in estuaries and coastal waters in many countries. In recent decades, human activities have considerably increased the delivery of nutrients to many estuarine and coastal areas. Eutrophic conditions include low dissolved oxygen concentrations, declining seagrasses, and harmful algal blooms; these conditions may impact the use of human health, estuarine, and coastal resources by reducing the success of commercial and sport fisheries, fouling swimming beaches, and causing other problems because of the decay of large amount of algae [2]. Large cyanobacterial bloom events are classified as “harmful algal blooms” if linked with negative environmental impacts such as a decrease in ecosystem stability, production of highly active toxic compounds known as cyanotoxins, and mortality [3]. The incidence of cyanobacterial blooms in freshwaters has increased over the past few decades owing to rising nutrient levels caused by intensive farming practices, sewage generation, and detergent usage [4][5].

Cyanotoxins present a hazard to drinking water safety and potential health threat for humans mainly after ingestion orally, through drinking water or consumption of food that could have accumulated cyanotoxins [6]. Hepatotoxicosis and neurotoxicosis are the most common syndromes caused by ingesting these blooms [7]. After acute contact with water from sources containing cyanobacterial bloom, the following health problems could possibly arise: abdominal pain; vomiting; diarrhea; weakness; irritation of skin and mucous membrane of the eyes, nose, and throat; asthmatic attacks; muscle tremors; nausea; tingling in fingertips and toes; blurred vision; headache; dizziness; fever; hypoxia; cyanosis; paralysis; and respiratory or cardiac arrest resulting in death [8][5].

Chlorophyll-a concentrations may be used to determine the trophic status of a dam. Chlorophyll is the green pigment in plant leaves that allows them to create energy light through photosynthesis. By measuring chlorophyll, the amount of photosynthesizing plants is indirectly measured. Chlorophyll is a measure of all green pigments whether they are alive or dead. Factors such as sunlight, temperature, nutrients, and wind affect both algae number and chlorophyll-a concentration. At Semberong Barat Dam (SBD), Johor, Malaysia, a long-term program is implemented to monitor its chlorophyll-a concentration. The measurements are conducted daily at fixed stations in the dam.

Background of study

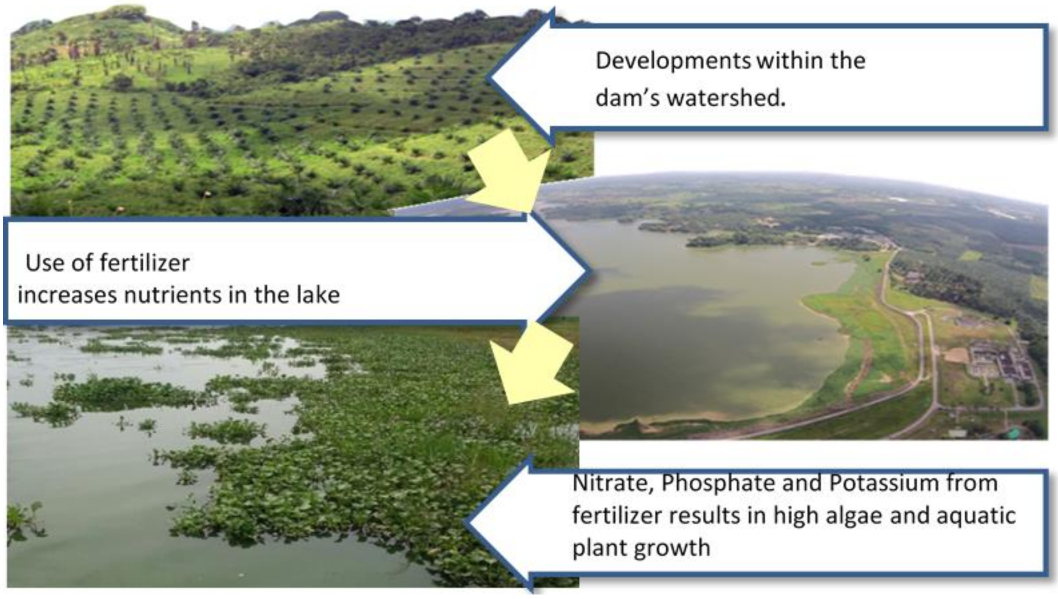
Sembrong Barat Water Treatment Plant (SBWTP) has been producing water below its design capacity, and this problem is mainly due to the unpredicted algae growth. Source water characteristic has changed after the initial plant design in 1990. The algal blooms can occur periodically because of an increase in nutrient load. Surrounding factors such as modern agricultural activities, soil runoff, and animal waste are the primary sources that enrich the nutrient in water, thereby leading to algal blooms. In SBD, Kluang, Johor, Malaysia, a problem of cyanobacterial blooms and cyanotoxins exists in its surface freshwater. This part of SBD is used as water supply reservoirs and irrigation systems. Since 2007, the water quality in SBD has shown conditions in aquatic ecosystems that are conducive to cyanobacterial bloom. The most dominant detected bloom-forming cyanobacteria species are *Oscillatoria* sp., *Spirulina*, *Asterionella*, *Peridinium*, *Coelastrum*, *Planktosphaeria*, *Scenedesmus*, *Rhodomonas*, and *Euglena*. All of these genera produce more than one type of toxins [7].

Algal blooms cause different problems in SBWTP. Algal blooms can result in various problems, such as the aesthetically unacceptable situation and increased production cost of water for potable purposes. The reasons are as follows: 1) the filter systems are usually clogged and scums are formed in purification plants 2) increased chemical dosages are necessary and more sophisticated treatment process is required to remove tastes, odors, and other by-products. The presence of algae can cause taste and odor problem. As one of the water operators in Johor, Malaysia, SAJ Holdings has made extensive investments in physical, managerial, operational, and quality assurance infrastructures to provide safe drinking water to its consumers. One of the initiatives implemented to overcome the algae problem is using green technology via ultrasound approach. With the water quality sensor and imaging system, early warning and restoration program can be smoothly applied scientifically. As an agency holder for Fluid Imaging and LG Sonic, Arachem (M) Sdn. Bhd. has been awarded to identify, monitor, and control algal bloom in SBD, Kluang, Johor, Malaysia. This study aims are 1) to remove and prevent the algae bloom in the raw water at SBD before feed to SBWTP and 2) to enhance the understanding of the function of sonic wave to disintegration of algae.

Eutrophication process in SBD

Eutrophication in SBD has risen from the oversupply of nutrients, thereby inducing the rapid growth of plants and algae. When such organisms die, they consume the oxygen in the body of water and thus creating the state of hypoxia. The primary limiting factor for eutrophication is phosphate. The availability of phosphorus promotes excessive plant growth and decay, favoring simple algae and plankton over other more complicated plants. Such presence also causes a severe reduction in water quality. Phosphorus is a necessary nutrient for plants to live and is the limiting factor for plant growth in many freshwater ecosystems. Phosphate adheres tightly to soil and is mainly transported through erosion. Once translocated to lakes, the extraction of phosphate into water is slow. Thus, reversing the effects of eutrophication becomes difficult. The sources of this excess phosphate are detergents, industrial/domestic run-off, and fertilizers. With the phasing out of phosphate-containing detergents in the 1970s, industrial/domestic runoff and agriculture have emerged as the dominant contributors to eutrophication in the SBD. Sodium triphosphate was once a component of many detergents and was a major contributor to eutrophication. Figure 1 shows the issue relating to the catchment development at SBD. . Health problems can occur where eutrophic conditions interfere with drinking water treatment [9].

Figure 1: Algae issue relating to catchment development at SBD



In SBD, human activities was accelerated the rate at which nutrients enter ecosystems. Runoff from agriculture and development, pollution from septic systems and sewers, sewage sludge spreading, and other human-related activities increase the flow of both inorganic nutrients and organic substances into ecosystems. Elevated levels of atmospheric compounds of nitrogen can increase nitrogen availability. Phosphorus is often regarded as the main culprit in cases of eutrophication in lakes subjected to "point source" pollution from sewage pipes. The concentration of algae and the trophic state of lakes correspond well to phosphorus levels in water. Understanding the level of eutrophication (chlorophyll-a) can be helpful to estuarine ecosystem management. In this regard, water quality and environmental monitoring have been used widely to assist water resource managers in developing control strategies for estuarine water quality management.

METHODS

Raw water quality

In this study, water samples were obtained from the SBD. Table 1 summarizes the quality of the raw water. Three units of MPC-Buoy were used and installed in the SBD. The FlowCAM imaging particle analysis system is a tool for detecting, identifying, and quantifying algae or problem particulate matter in water treatment processes. Based on the knowledge of the authors, this study is the first to apply the MPC-Buoy in Malaysia.

Numerous studies have indicated that ultrasonic irradiation can inhibit eutrophication by breaking down gas vesicles in algae cells. The ultrasonic irradiation also inhibits the process of photosynthesis and thus controls algae growth. Moreover, ultrasound application is considered a pollution-free “green chemical technique” and may have a promising future for the monitoring of algae growth [10]. A few studies have directly examined the effect of ultrasonic irradiation on enhancing coagulation for algae removal. In water treatment, removing algae cells is difficult because of particular characteristics such as negative surface potential; another reason is that their metabolites are prone to adsorb colloidal particulates [10]. Figure 2 (a) shows the MPC-Buoy image, and Figure 2 (b) shows the location of the MPC-Buoy units in SBD.

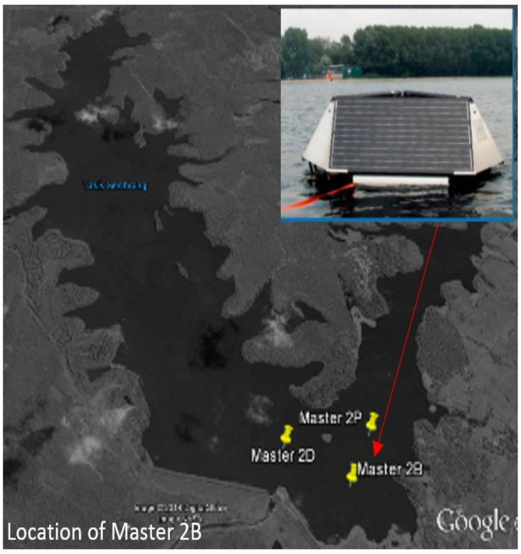


Figure 2(a): MPC-Buoy image

Figure 2 (b): Location of MPC-Buoy

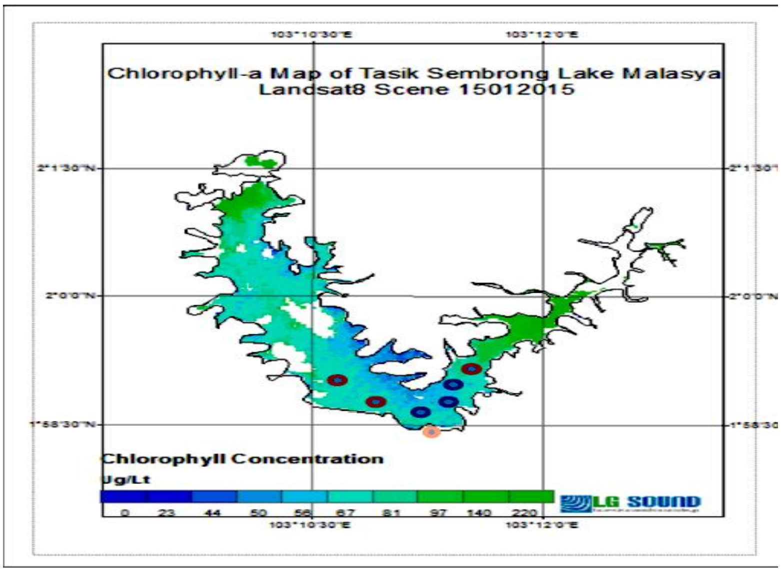


Figure 3: Current location of MPC-Buoy in SBD. (*Existing Buoy *Proposed additional unit)

Table 1: Summary of the quality of the raw water

Parameters	Instruments used	Value
pH (Units)	Sension pH meter	6.9–9.5
Turbidity (NTU)	Turbidity meter	25–30
Color (True Color Units)	DR 890	120–200
Aluminum (mg/L)	DR 890 / ICPMS	0.00
Iron (mg/L)	DR 890 / ICPMS	0.20–0.4
Ammonia (mg/L)	DR 890	0.7–1.3
Manganese (mg/L)	DR 890 / ICPMS	0.1–0.6
Oscillatoria (μg/L)	FlowCAM	98856
Actual algae (μg/L)	FlowCAM	99263
Chlorophyll (μg/L)	FlowCAM	50

Ultrasonic irradiation can alter the characteristics by breaking down the gas vesicles in algae cells, thereby achieving better algae removal efficiencies by enhanced coagulation. This study aimed 1) to identify and quantify algae presence in the Sembrong Lake through FlowCAM imaging and 2) to better understand the algae disintegration using sonication treatment. Figure 3 showed the current location of the MPC-Buoy and the proposed additional unit in SBD. Sonolysis is the best application in conjunction with an advanced oxidation technologies; different from most advanced oxidation technologies, ultrasound does not require the addition of chemicals; hence, this technology is more suitable for algal blooms [11].

Measuring instrument

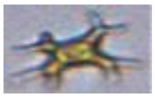
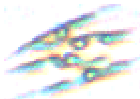
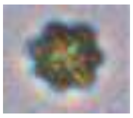
The FlowCAM Benchtop VS Series from the United States supplied and managed by Arachem (M) Sdn. Bhd, was used for algae count and identification.

Monitoring and control

ISSN: 0975-8585

The MPC-Buoy units were moored in the middle of the lake and attached to two 50-kg weights to keep them in place. The LG Sonic MPC-Buoy will monitor the water quality, and based on that design, an accelerated program will be developed to combat the algae. The range of the sonic wave dispersions by MPC-Buoy was set to 500 m diameter. The MPC-Buoy measures water quality by collecting information every 30 min, including phycocyanin (indicating the level of blue-green algae), chlorophyll-a (indicating the level of green algae), water clarity (turbidity), pH (acidity), dissolved oxygen levels, and temperature. Determining the types of algae that are present in SBD is important. This activity is essential to assist the water treatment plant and management in deciding the further direction of water treatment in SBWTP. Table 2 shows the type of algae species in a sample collected near the intake point. The MPC-Buoy was set up with 20 Hz –2 MHz wavelength.

Table 2: Type of algae species in sample collected near the intake point

Scenedesmus		***Rhodomonas***		***Staurastrum***	
Aulacoseira		***Ankistrodesmus***		***Clostridium sp***	
Spirulina sp.		***Cryptomonas***		***Euglena sp.***	
Oscillatoria sp.		***Peridinium sp.***		***Botrycocus***	
Chlorella		***Coelastrum***		***Navicula sp***	
Mucus		**Copepod**		**Zooplankton**	

Mathematical reproduction

The mechanism of disintegration on algae cell from aqueous solutions consists of the following three successive steps. First is the disintegration of the cell wall or the cell membrane (external site), second is the disintegration of cytoplasm (internal), and third is the global disintegration on algae. The data monitoring concentrations of the algae pollution before and after the outlet of the MPC-Buoy were used in this study to develop the continuous equations. Based on the concentrations of penetration of sonic, periodically monitored in the entrance and exit of the system, the equation of disintegration balance "Global breaking = Osmosis + Cell wall disintegration" was developed and written as

$$QC = Q\times(C-\partial C)-[K_L]_f\times S\times(C-C^*), \quad 1$$

where Q is the flow rate (in L/h) and C is the concentration of the solution (in $\mu g/L$). Equation (1) was modified into the form of the differential equation of film mass transfer [12][13] thus,

$$-\partial c/\partial t = [K_L]f\times S\partial V\times(C-C*), \quad 2$$

where V is the volume of the treated water (in L).

By integrating Equation (2) from $C=Co$ to $C=Cs$, from $V=0$ to $V=V$, from $t=0$ to $t=t$ [where $S/V=a$ is the surface of interfacial liquid solid (in 1/m)], and considering the condition of C^*C [14] a continuous equation was obtained as

$$Log\left(\frac{C_0}{C_e}\right) = [K_La]_f * t, \quad 3$$

where Co is a concentration of the solute to enter into the column (mg/L), and Cs is a concentration of the solute to depart from the column ($\mu g/L$). K_L is mass transfer coefficient (m/h), and a is the surface of interfacial liquid–solid (m^{-1}). $[K_La]_f$ is film mass transfer factor or external mass transfer factor or volumetric film mass transfer coefficient (h^{-1}), and t is accumulation time (h). In addition to the enhancement of mass transfer, shock waves from cavitation in liquid–solid slurries produce high-velocity intraparticle collisions. In this study, the modified mass transfer factor models were amended to determine the strength of sonic radiation to algae and were rewritten as

$$Log\left(\frac{C_0}{C_s}\right) = D_\gamma\ x\ e^{-\beta x Log\,(a)} x\ \mathrm{t} \quad 4$$

where Co is the initial chlorophyll-a concentration ($\mu g/L$), Ce is the final chlorophyll-a concentration (μg/100 mL), and α is the osmosis diffusion rate of algae ($\mu g/L$). A deduction of Equation (4) mathematically provides the linear expression of contravention as

$$\mathrm{Log}\left(\frac{C_0}{C_s}\right) = D_\gamma * t, \quad 5$$

where $D\gamma$ is the global breaking of algae cells ($\mu g/L$). To acquire a linear expression, Equation 5 was rewritten as

$$Log\,(q) = B + \frac{1}{\delta} * log\,(t), \quad 6$$

with

$$B = \frac{Log\ D_\gamma - Log\ \{\log(\frac{C_0}{Ce})\}}{\delta}, \quad 7$$

where B is potential sonic wave impact on the algae cells relating to the driving force of algae cell disintegration ($\mu g/L$) and δ is the affinity between sonic wave and algae cells ($\mu g/L$). Calculating the lysis of the cells (D_α) by osmosis process and cell membrane/cell wall disintegration (D_β) using the following expression is important:

$$D_\gamma = D_\alpha + D_\beta \quad 8$$

In order to increases the understanding of algae trending in SBD, it is important to know the movement of alae disintegration trending. Fourier coefficient analysis was applied in this study. The basic equation of Fourier coefficient analysis stated as follow:

$$y = \frac{a_0}{2} + \sum_{n=1}^{\infty}\left[a_n cos\frac{2n\pi x}{T} + b_n sin\frac{2n\pi x}{T}\right] \quad 9$$

Where a_0, a_n, b_n are Fourier coefficient, x is water quality parameters, ∞ is infinity and T is time. The cos and sin are representing Fourier trigonometric equation. The value of a and b from the regression analysis is used to develop the equation analysis and in this study the final equation for a_n was written as:

$$a_n = \frac{2}{T}[2.0138[cos\ 2n\pi ft + t\ sin\ 2n\pi ft]_0^t - [0.2665\ sin\ 2n\pi ft]_0^t\ ] \qquad 10$$

And the equation of b_n was written as:

$$b_n = \frac{2}{T}[2.0.138[sin\ 2n\pi ft + t\ cos\ 2n\pi ft]_0^t - [0.2665\ cos\ 2n\pi ft]_0^t\ ] \qquad 11$$

The value of *a* and *b* from the regression analysis in this study is written as (Figure 7):

$$f(x) = 2.0138x - 0.2265 \qquad 12$$

RESULTS AND DISCUSSION

Blue-green algae are dominant in the sample studied from November 2014 to December 2015; the dominant specie is *Oscillatoria*. The algae count is nearly stagnant and fluctuated at this point. This phenomenon is due to the lack of ultrasound treatment installed near the intake point. The impact of ultrasonic irradiation on the organic substance in raw water was examined to identify the effectiveness of the ultrasonic wave used. As shown in Table 3 and Figure 4 , the chlorophyll count decreased. Nearly 83% of chlorophyll-a cell successfully decreased because of the algae elimination by MPC-Buoy during the trial period of the research.

From the data obtained, the temperature played the significance role in the algae formation. This parameter directly affected the efficiencies of MPC-Buoy in algae removal. Dissolve oxygen level has also attributed to the breakdown of algal cells, and indicates that the photosynthesis activities significantly correlated with the temperature. Sonication significantly enhances the reduction of algae cells, without increasing the concentration of aqueous microcystin. Application of ultrasonic irradiation requires frequencies that lead to extreme conditions. Table 3 shows the main chemical and physical parameters of raw water characteristics during the experimental period from two weeks after the installation of MPC-Buoy units until day 427 (from November 2014 to December 2015).

Algae deduction analysis

As shown in Table 3 and Figure 4, water passing through the MPC-Buoy radiation provided a slight reduction in the pH values compared with the plant intake water (from 7.19 to 9.02 as mean values for the entire monitoring period), indicating that the radiation slightly changed the alkalinity from the water. The dissolved oxygen values also fell drastically after passing through radiation. This result is probably due to the algae cell breakdown. The radiation has eliminated some of dissolved oxygen contents.

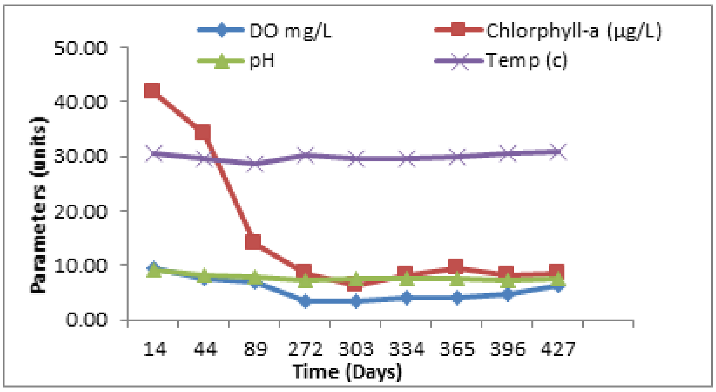


Figure 4: Trending of the main parameters in SBD raw water

Table 3: Chemical and physical parameters of raw water characteristics during the experimental period

Days	DO mg/L	pH	Temp (c)	Chlorophyll-a (µg/L)	
14	9.36	9.02	30.69	41.82	
44	7.54	8.16	29.53	33.95	
272	3.40	7.21	30.13	8.44	
303	3.45	7.58	29.63	6.15	
334	4.04	7.58	29.49	8.00	
365	3.96	7.44	30.02	9.49	
396	4.49	7.19	30.46	8.13	
427	6.29	7.40	30.83	8.62	

The data in Figure 4 showed the downward trend of chlorophyll-a from the date of MPC-Buoy installation until the last day of research. This trend shows that the use of ultrasonic devices successfully reduced the algae and chlorophyll-a levels in SBD raw water from 41.82 µg/L to 8.62 µg/L. Dissolve oxygen was slightly fluctuated from 3.40 mg/L to 9.36 mg/L and pH range between 7.19 units to 9.02 units. Thus, the study showed the effectiveness of the sonic wave ultrasonic to reduce the chlorophyll-a levels in the raw water. [15][16] reported the irradiation was effectively inhibited cyanobacterial proliferation rapidly destroyed chlorophyceae , and prevented bloom formation in water [17].

Impact of ultrasonic irradiation on chlorophyll-a count in raw water

As discussed above, the use of the equation is necessary to evaluate the effectiveness of the sonic wave generated from the MPC-Buoy on the destruction of algae. By using Equation (6), the regression analysis was performed. The experimental data in Figure 5 show the regression analysis of chlorophyll-a forming. The correlation coefficient between cumulative and time showed a good value (R^2=0.9894). The values of driving force (β) and B were -0.2665 and 2.0138 µg/L respectively. Equation (6) allows us to determine the disintegration rates based on the sonic wave. Whenever an imbalance of sonic wave occurs in a medium, the sonic wave naturally redistributes until balance or equality is established. This tendency is often called the driving force and is the mechanism behind many naturally occurring transport phenomena. To balance the number of a sonic wave per unit volume, the flow of sonic wave is always in the direction of increasing (D_β) the high driving force (from low to a high concentration gradient).

The wave (D_α) gradually moves away from areas of high concentration during redistribution, resulting in a lysis of algae cells. The proportionality constant is the diffusion coefficient of the sonic wave and osmosis, measuring how much the sonic wave diffuses in algae cells. The algae cell has a cell membrane that protects the cytoplasm. The cell wall is located outside the cell membrane of plants, algae, fungi, and many prokaryotes. The main function of cell walls is to support and protect the cell membrane. The most important part of the algae cell is the nucleus, which is the control center of the cell and contains DNA that has instruction for making proteins and other molecules. D_γ values were calculated according to Equation (7) because the curve is crucial for assessing the global breaking of algae cells. Thus, a plot of D_γ versus the t (days) can be proposed. The experimentally produced curve traces of D_γ based on the sonic wave driving force and the cumulative variations of the curves for both D_α and D_β were defined by Equation (8) (Figure 6).

D_γ in Figure 6 shows the global breaking of algae cells is achieved after sonification disintegration (Eq. 8), while D_β, shows the graph ascending upward from left to right, representing the disintegration rate of the cell wall when the sonic wave has passed through algae cells. The data showed the ascending has started on the second months of the observation. Similarly, $D\alpha$ shows the graph decreases from left to right representing the osmosis process occurring within the cell cytoplasm and that this part of the cell will eventually burst after the cell wall is ruptured. Therefore, an increase in the disintegration rate will increase the rate of osmosis process until it reaches equilibrium. Ultrasonic wave has used low power output but with high frequency. The algae will adsorb the energy that been carried by the ultrasonic wave, vibrating and then disrupted the algae cells. As it vibrating, the hydrogen bond of the cell wall and cytoplasm, as well as the gas vesicle [17] of the algae was break down because of the resonance frequency that been achieved [18]. The graph D_β show the sound energy that produced from the MPC buoy was used at maximum capacity to disintegrate the algae cells, due to high quantity of algae in raw water and started to optimize at the month three. The graph D_β shows the energy that has been adsorbed by the algae. Figure 6 shows D_β indicating that cavitation will occur when the ultrasonic is applied in the medium at high energy levels. Cavitation is the formation of resonating cavities or bubbles. In water, cavitation occurs with ultrasound excited with power more than 0.33 W/cm^2 [19]. Cavitation can be divided into two types: non-inertial cavitation and inertial cavitation [20]. As non-inertial cavitation occurs, the cavitation bubble remains stable during each sound cycle. During inertial cavitation, the bubble grows and becomes unstable in the end; then the bubble collapses and generates high pressure and temperatures, causing the formation of reactive free radicals, such as the hydroxyl radicals [19]. Given the mechanical, physical, and chemical forces created by cavitation, destructive effects on living cells can be expected [21]. This phenomenon will relate with the osmosis process that occurs within the cell. After irradiation by the ultrasonic wave, the free radicals (OH^-) significantly affect the membrane permeability and active transport process [17].

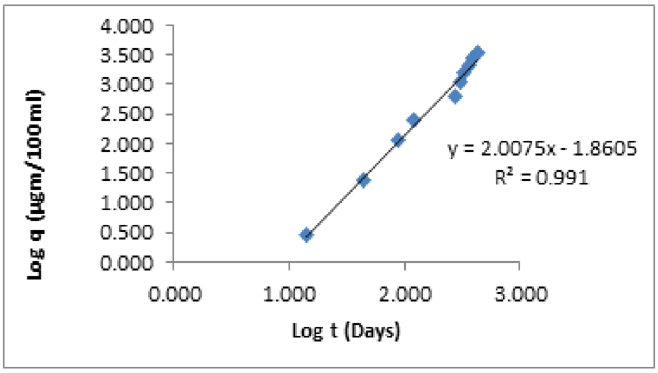


Figure 5: Regression analysis of Log cumulative vs Log t (Days)

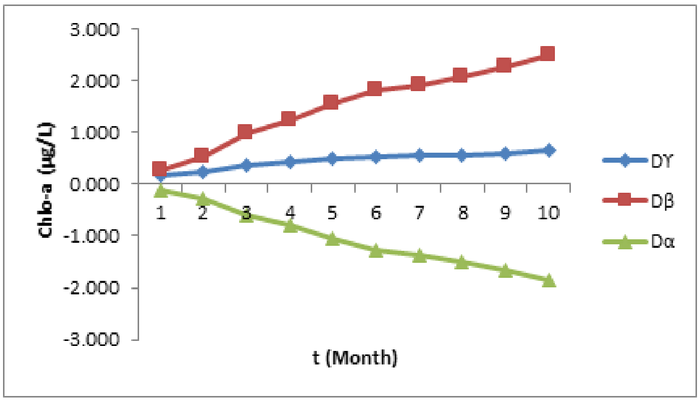


Figure 6: Value of D_γ, D_β, and D_α redistribution effected by sonic wave

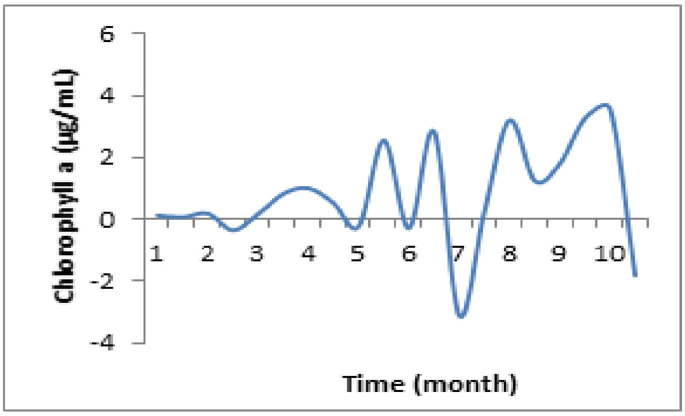


Figure 7 (a): Fourier analysis on pH (monthly)

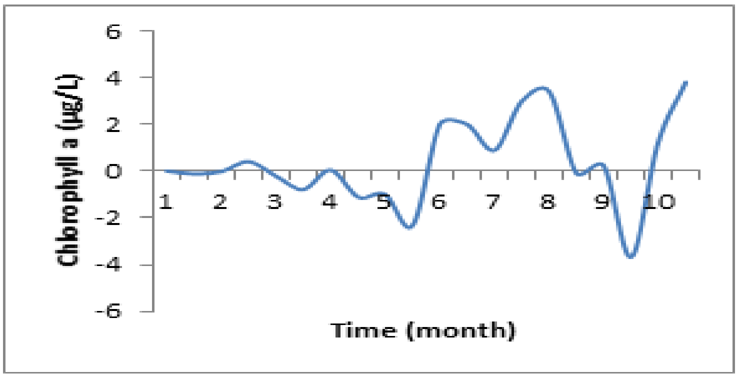


Figure 7 (b): Fourier analysis on DO mg/L (monthly)

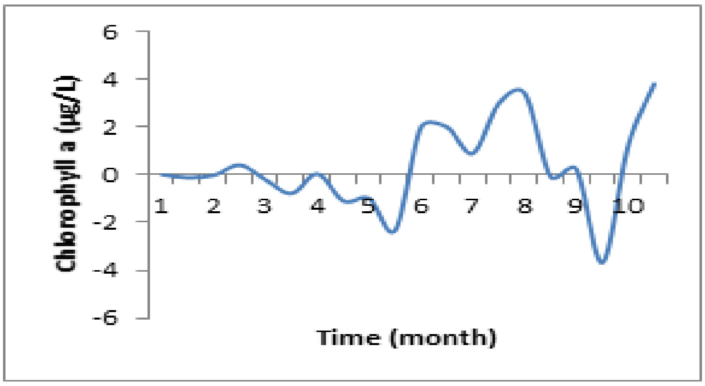


Figure 7 (c): Fourier analysis on temperature ^{o}C (monthly)

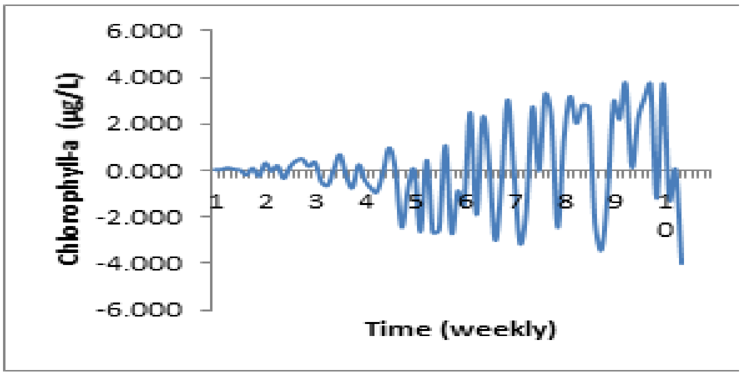


Figure 7 (d): Fourier analysis on pH (weekly)

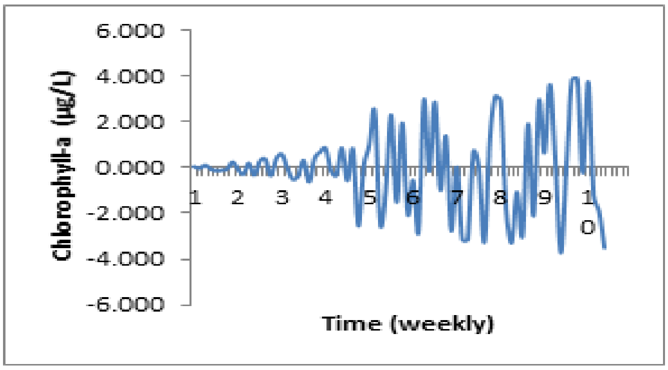


Figure 7 (e): Fourier analysis on DO mg/L (weekly)

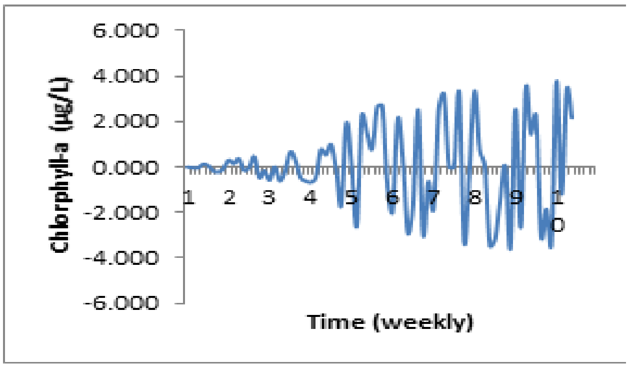


Figure 7 (f): Fourier analysis on temperature °C (weekly)

The ratio between the surface area and volume of cells and organisms has an enormous impact on their biology (the physiology, behavior, and other qualities of a particular organism or class of organisms). For example, many aquatic microorganisms have increased surface area to enhance their drag in the water. Such enhancement reduces their rate of sink and allows them to remain near the surface with less energy expenditure. An increased surface area to volume ratio also means increased exposure to the environment. D_α in Figure 9 shows that the osmosis process that occurs during the cell wall of the algae cell has caved in because of the breaking of hydrogen bond of the cell wall. The rupture of the cell wall leaves the cytoplasm expose to the environment. The high concentration gradient of the cell than the surrounding medium will force the cell to absorb more water through simple diffusion and intracellular material release to the medium [22]. As a result, the cell will break because of the absence of cell wall to retain its shape.

Accordingly, the amount of single and multi-cell algae disintegrate by sonic wave should be less than the total quantity of total algae into polluted water. The model proposed in this study is based on mass transfer equation and has been verified for the definitions of global, external, and internal disintegration transfer from the sonic wave dispersions onto the algae cells. Many different situations are classified as wave dispersions. As the continuity of the above findings, it is important to perform the prediction of the algae growth in SBD raw water. Due to that the Furious trigonometry method was applied to calculate the future algae growth. Furious trigonometry method was applied because of capability of feature extraction and considering unknown physics characteristics of the Chlorophyll-a phenomenon, provided more established and accurate forecasting results than the regular artificial neural network model. By applying equation (10 and 11), the following graph was execute. Figure 7 showed the a_n and b_n graph on monthly analysis using the original Chlorophyll-a time series. Figure 7 (a) (monthly) and Figure 7 (d) (weekly) showed the range of pH which was predicted to optimizing the algae growth. Higher level was -0.004 and the lowest value were -0.0031 which was equal to 0 mV and -101mV. The average pH for the raw water in this study is -42.29 mV. Since dissolve oxygen is by-product from the photosynthesis activity by algae (Figure 7 (b) and (e)) the dissolve oxygen was observed as the algae growth indicator. The most important parameter that's influence the algae growth is the significant of temperature. Figure 7 (c) and (f) showed the range of temperature in this research. The maximum value of temperature was 0.004 and the minimum value also was 0.004. The average value of temperature in this study is 29.82° C.

Ideally, all of these situations can be modeled using the most general equation of wave, if possible. The correlation between models and theories is developed to systematically understand the models. The theory of eutrophication management and control is based primarily on limiting the nutrient release into the water bodies [23]. Preventing nutrient release is a long-term mission. Controlling the irradiation duration in the dam is also difficult if the pollution and nutrient are continuously fed to the algae. The ultrasonic irradiation can serve as an emergency solution because this technology can ensure continuous water supply even if the eutrophication exists. However, proper operating conditions should be pre-set for algae removal by coagulation. The ultrasonic frequency, power supply, and irradiation duration are considered the key parameters for determining the degrees in which the algae cells are destroyed. This study suggests that ultrasonic irradiation works effectively for algae removal by enhancing coagulation. Figures 6 and 9 demonstrate the frequencies for expediting algae removal using the sonic wavelength. Ultrasound power is an important element of the sonochemistry [24]. High ultrasound power creates more cavitations and accelerates reactions [25].

CONCLUSION

The current coverage zone of MPC-Buoy for algae treatment is limited due to the large area and high water velocity. Algae tend to reproduce and grow. Installing additional buoy and e-line can achieve further reduction. Based on the algae indicator, algae concentration is dramatically reduced by approximately 87% within 427 days. In addition, the unpleasant smell is removed. Accordingly, better source water quality is provided and thus indirectly helps reduce operation cost in production especially in chemical saving and backwash frequency. Moreover, the ultrasound frequency is a decisive factor for algae removal. Application of ultrasonic irradiation mainly intends to decrease the aggregation of algae. Contrary to direct coagulation without pre-treatment, the ultrasonic irradiation can improve the quality of treated water without secondary pollution. Although optimal ultrasound parameters are determined, the technique showed a good impact on the algae disintegrations. The equation developed is significant to determine the phase of algae disintegration.

ACKNOWLEDGMENT

This work was supported by the SAJ Management with highly appreciated. Appreciations also addressing to Faculty of Bio Science and Health Engineering, Universiti Teknologi Malaysia, and the Ministry of Malaysia Higher Education on the valuable encouragement.

REFERENCES

[1] Tu, J.V.. Advantages and disadvantages of using artificial neural networks versus logistic regression for predicting medical outcomes. J Clin Epidemiol1996;11(49):1225–31. Elsevier, 1996.

[2] Duda, A., M. Municipal point source and agricultural nonpoint source contributions to coastal eutrophication. Water Resource. Bull, 1982;18:397–407.

[3] Chorus, I. (Ed.). Cyanotoxins – Occurrence, Causes, Consequences. Springer- Verlag, Berlin, Heidelberg; 2001.

[4] Reynolds, C.S. Cyanobacterial water blooms. In: Callow, J.A. (Ed.), Advances in Botanical Research. Academic Press, London, 1987, pp. 67–143.

[5] Svircˇev, Z., Baltic´, V. Cyanobacteria and Human Health. Abstract Book. Academy of Studenica, Novi Sad, 2011.

[6] Svircˇev, Z., Simeunovic´ , J., Subakov-Simic´ , G., Krstic´ , S., Vidovic´ , M. Freshwater cyanobacterial blooms and cyanotoxin production in Serbia in the past 25 years. Geogr. Pannonica 11, 2007; 32–38.

[7] Haider, S., Naithani, V., Viswanathan, P.N., Kakkar, P. Cyanobacterial toxins: a growing environmental concern ,2003, Chemosphere 52: 1–21.

[8] Chorus, I., Bartram, J. (Eds.). (Toxic Cyanobacteria in Water: A Guide to their Public Health Consequences, Monitoring, and Management. E & FN Spon, London, UK, 1999.

[9] Codd, G.A. Cyanobacterial toxins: occurrence, properties and biological significance. Water. Sci. Technol ,1995; 34: 149–156.

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

[11] Catherine, Q., Susanna W.E.S., Mark, H., Aurélie, V., Jean-François H. A review of current knowledge on toxic benthic freshwater cyanobacteria – ecology, toxin production and risk management, Water Res., 2013; 47 5464– 5479.

[12] Bersillon J.L., Leprince A., Fiessinger F. (1986). RO mathematical modeling as a tool for the practitioner, Water Supply 4 ,1986; 23–33.

[12] Fulazzaky, M.A. Analysis of global and sequential mass transfers for the adsorption of atrazine and simazine onto granular activated carbons from hydrodynamic column, Anal. Methods 4 ,2012; 2396–2403.

[13] Roslan, O., Abd Aziz, A.L., Rafiddah, H., Elias, I., Zailan, Z., Azlin, S., Shazatul Irwan, O., Siddiq, M. Adsorption Mechanism: Synthetic Inorganic and Synthetic Organic Competition Onto Adsorbent – International Journal of Civil & Environmental Engineering IJCEE-IJNS ,2016; Vol. 16, No:02, 07-18

[14] Hao H.W.,. Wu M.S, Chen Y.F., Tang J.W.,. Wu Q.Y, Cavitation mechanism in cyanobacterial growth inhibition by ultrasonic irradiation, Colloid Surf, 2004; B: Biointerfaces 33 151–156.

ISSN: 0975-8585

[15] Dehghani, M.H. Changani, F. The effect of acoustic cavitation on Chlorophyceae from effluent of wastewater treatment plant, Environ. Technol. 27 ,2006; 963–968.

[16] Mahvi, A. H., & Dehghani, M. H. Evaluation of ultrasonic technology in removal of algae from surface waters. Pakistan Journal of Biological Sciences, 2005.

[17] Schneider, O. D., Weinrich, L. A., Brzezinski, S. Ultrasonic Treatment of Algae in a New Jersey Reservoir, 2015; 533–542.

[18] Adewuyi, Y. G. Sonochemistry: Environmental Science and Engineering Applications. Ind. Eng. Chem. Res., 40, 2001, 4681-4715.

[19] Leighton T.G. (2007), *"What is ultrasound",* Progress in Biophysics and Molecular Biology 93, 3-83.

[20] Antoniadis, A. Sonochemical disinfection of municipal wastewater. Journal of Hazardous Materials, 146, 2007; 492–495.

[21] Jeon B.H., Choi J., Kim H., Hwan J. *Ultrasonic Disintegration of microalgal biomass and bioaccesibility/ bioavaibality in microbial fermentation, 2013.*

[22] Smith, V.H., Tilman G.D, J.C. Nekola, *Eutrophication: impacts of excess nutrient inputs on freshwater, marine and terrestrial ecosystems*., 1999 Environ. Poll., 100, 179–196.

[23] Zhang, G.M., Zhang, P.Y., Wang, B., Liu, H. Ultrasonic frequency effects on the removal of Microcystis aeruginosa., 2006 Ultrasonics Sonochem., 13 446–450.

[24] Phull, S.S., Newman, A.P., Lorimer, J.P., Pollet, B., Mason, T.J.(1997). The development and evaluation of ultrasound in the biocidal treatment of water., 1997, Ultrasonics Sonochem., 4, 157–164.