COMPARATIVE WATER QUALITY STUDY BETWEEN PEAT COAGULANT TREATED AND UNTREATED MODEL WATER BODIES

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ABSTRACT

Locally invented coagulant from Malaysian peat soil was effective for the clarification of lake and river water. Study was performed on stagnant lake water using model water bodies treated with peat coagulant. Better water quality was found in peat coagulant treated lake water compared to the lake water without peat coagulant treatment. The Dissolved Oxygen (DO) level recovered to the original value within two to three weeks in peat coagulant dosed tank. For the control tank the DO level was as low as 0.8 mg/L and the DO level never reached the original value even after sixty days of monitoring. The other water quality parameters like Chemical Oxygen Demand (COD), nutrients (P and N) and suspended solids were lower than those of the control tank.

Keywords: peat coagulant, water quality, lake water, model water bodies.

1. INTRODUCTION

Fresh water in a country or region is the total amount of water present in the lakes and rivers. As a result of over industrialization and alarming population growth in most of the developing countries, proper management of these fresh water sources has become an important issue. Globally, there are lots of problem arising for the quality and quantity of water and in some cases it is getting more serious. These problems also include increased water consumption due to population growth, contamination of drinking water by introducing hazardous wastes and wildlife destruction through water pollution. Industrial and domestic wastes are frequently allowed to discharge in the river or lake without proper treatment. This usually leads to an unwanted nutrients and other toxic chemicals introduction in the fresh water sources (Haughey *et al*., 2000).

Lakes are often classified as oligotrophic or eutrophic depending on their productivity. Oligotrophic lakes are characterised by low nutrient inputs, low to moderate plant production and relatively clear water. Whereas eutrophic lakes have high nutrient inputs, high plant production, turbid water with bad smell and toxicity (Janssen, 2001). Scientific studies proposed different ways for the management of the lake water environment. Smith *et al*. (1999), Soyupak *et al*. (1997) and Gilliam (1995) have proposed to mange the eutrophication by controlling the point and non point nutrient sources. Applying metal salts for the control of algal growth showed reasonable success for the lake management (Haughey *et al*., 2000). Use of curtain to reduce the nutrient supply showed better algal control (Asaeda *et al*., 2001). Using direct filtration method to get rid of the algae could be adopted (Tabatabai *et al*., 2014). Removal of the phosphorous loading by dredging and diverting the river water through the lake was the restoration solution reported by Jiang and Shen (2006) to treat the lake Donghu at Hubei province China. Through coagulation process using ferric and alum coagulant (Jiang *et al*., 1993) and spreading clay particle in lakes and estuaries for removing the algae (Han and Kim, 2001) are the ways and means used to manage the lake water quality. In another study Schussler *et al*. (2007) reported that proper management of phosphorous input and output can prevent eutrophication in lake.

The objective of this work was to study the viability of the peat coagulant (Mohd Asri *et al*., 2002) for the treatment of the model water bodies. Peat coagulant prepared from local peat soil was proven effective for the removal of turbidity from lake and river water (Mohd Asri and Mohd Zaidi, 2005). It was also reported to be effective for textile dye removal from aqueous solution as well as textile waste water (Helal Uddin, 2003; Helal Uddin *et al*., 2003). These studies showed that peat coagulant is able to remove the colloidal substances causing turbidity in the lake and river in the laboratory scale study. To study the handling of larger volume of lake water and the related parameters, model water bodies with a larger amount of lake water was employed. The model water body was used to imitate the lake environment in terms of depth. To avoid the other factors like diffusion, the study was performed in a closed system. The outcome of this study will be helpful for the subsequent step of study, which is to study the plausibility of applying the peat coagulant directly inside the lake and river either separating them in different segments simultaneously.

2. MATERIALS AND METHODS

Peat coagulant used for the experiment was prepared according to the procedure described by Mohd Asri *et al*. (2002). Peat coagulant solution used was 3.95% (w/v) solution. Perspex container of 30 cm length, 30 cm width and 30 cm height, was used to study different techniques of applying peat coagulant like spraying and aeration. Perspex containers of 15 cm length 15 cm width and 60 cm height were used for optimising the dosage of the peat coagulant by aeration technique. Two cylindrical fibreglass containers each of 2 m height and 0.5 m radius were used as a model water body.

2.1 Design and installation of the model water bodies

Two cylindrical fibreglass containers having 0.5 m radius and 2 m height were fabricated and placed under a roofed but open structure. The depth of the tank was modelled according to the depth of the lake where the water was taken. The whole set up was located beside the Lake Harapan in Universiti Sains Malaysia, Penang, Malaysia. The filling up of the tanks with lake water was done by directly pumping the lake water into the tanks up to the level of 1.5 meter. The total volume of the water was 1178 litres. Water samples were collected from the four outlets of the tank i.e. at 13 cm, 53 cm, 93 cm and 133 cm for water quality analysis.

A total of 706.8 ml peat coagulant at the ratio of 0.6ml/L (0.6 ml X 1178 L= 706.8 ml) was added to one of the container and was considered as experimental tank (ET) and the other tank was kept without adding anything and considered as control tank (CT). Peat coagulant was mixed using the aeration technique. Commercially available air cylinder was used to aerate the water while adding the peat coagulant at a constant flow rate by adjusting the pressure at 3-4 bar. Then treated water was allowed to settle and samples were collected regularly for monitoring.

2.2 Water quality monitoring

Among the water quality parameters for samples, inorganic phosphate was determined using standard methods (APHA, 1992); dissolved oxygen (DO), Chemical Oxygen Demand (COD), Turbidity (FTU) were determined using HACH (1992) method. Ammonia nitrogen was determined by the method suggested by Harwood and Kuhn (1970) and USEPA SOP (1994) was followed for the determination of the chlorophyll content. Calibration curve was prepared for the determination of inorganic phosphate and ammonia nitrogen of the water sample using standard solutions. Proper dilutions of the samples with higher concentration of nutrients were made with distilled water.

3. RESULTS AND DISCUSSIONS

Preliminary experiments in the laboratory were done in order to determine the optimum dosage values and the mode of coagulant application. Subsequently, aeration technique was chosen based on this preliminary study whereby water was aerated during the dosing of the coagulant. It was found that via this technique, shorter time was required for the optimum clarification of the water compared to the spraying technique. Moreover through aeration, better mixing of the coagulant was assured as it is a very important condition for the coagulation to occur (Benefield *et al*., 1982). The optimum dosage required to obtain maximum clarity was 0.6 ml/L which was later used for the calculation of the amount of peat coagulant required to apply in the experimental tank (ET).

Water quality of the model water bodies namely the control tank (CT) and the experimental tank (ET) were monitored for 2 months. The parameters monitored were DO, turbidity, COD, nutrient and algae. In order to see the effect of depth on the water quality, samples were collected at the specified depths using the equipped corresponding outlets.

Within the two months of water quality monitoring of both tanks, CT water became septic with dissolved oxygen level (DO) at 2.2 mg/L even though other areas of water quality parameters improved. The change was solely due to the natural cleansing of the system whereby natural decomposition and sedimentation played a big role. The water quality of ET tank treated with peat coagulant did not become septic with DO level at 5.0 mg/L and with overall better water qualities than that of CT. The mechanics of those changes that took place in both tanks will be the focus of discussion in the following sections.

A typical water quality of Lake Harapan water is given in Table-1. This water was sampled just before starting the experiment. Table-1 also provided the water quality results of both CT and ET at their bottom point (133 cm) after the end of the study which was about 2 months.

Table-1. Comparative water quality results of Lake Harapan water before treatment, the control tank (CT) and experimental tank (ET) water at the end of the study that lasted for 2 months.

Water	**Turbidity** (FTU) (mg/L)	**Dissolved oxygen** (DO) (mg/L)	**Chemical oxygen demand** (COD) (mg/L)	**Phosphate** (mg/L)	**N-Ammonia** (mg/L)	**Chlorophyll a** (mg/ml)	**Chlorophyll b** (mg/ml)
Initial	65	5.6	47	0.18	0.04	2.68	0.78
[a]CT tank	8	2.2	30	0.05	0.016	ND	ND
[a]ET tank	3	5	19	0.03	0.005	ND	ND

[a] Water quality values at the end of 2 months period.
ND = non-determinable

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3.1 Dissolved oxygen (DO)

After adding the coagulant in ET, the algae and the colloidal particles formed sludges and started to float after several hours, which was removed from the surface of the water. On the other hand, for CT tank, the algae was dispersed throughout the water body. With time, this alga slowly settled to the bottom of the tank.

The DO contents of both tanks were monitored just after three days of standing for the purpose of equilibration. From Figure-1, the DO profile of both tanks can be compared. A sudden drop of the DO compared to the initial DO was observed for both CT and ET at every point. For both tanks there was a decomposition activity, which required oxygen and it was reflected in the DO profile from their sharp decrease within the first few days. Compared to ET the DO of CT was lower because of the greater decomposition activity. After that, both tanks began to regain the DO at every sampling point. However, the rate of DO recovery of ET was much faster as compared to CT. As seen oxygen recovery process for ET tank began after one week and almost reached the initial DO level on the 8th week whereby it was 5.3 mg/L at top and 5 mg/L at the bottom point of ET. In case of CT, no significant oxygen recovery was observed and DO level remained at 2.7 mg/L at the top and 2.2 at the bottom point on the 8th week. This indicates that within this time period, decomposition process was not yet completed. Decomposition of the algae at the bottom of CT consumed the oxygen causing a lower DO concentration in CT. Whereas in ET the decomposition activity was much lower compared to CT because of the removal of algae at the beginning of the experiment. Usually in lake and river waters DO and depth levels are inversely proportional to each other (Ellis, 1989). This is due to the greater exposure of upper layer to the environment and the oxygen can easily be transferred to the upper layer compared to the bottom layer (Manahan, 1994).

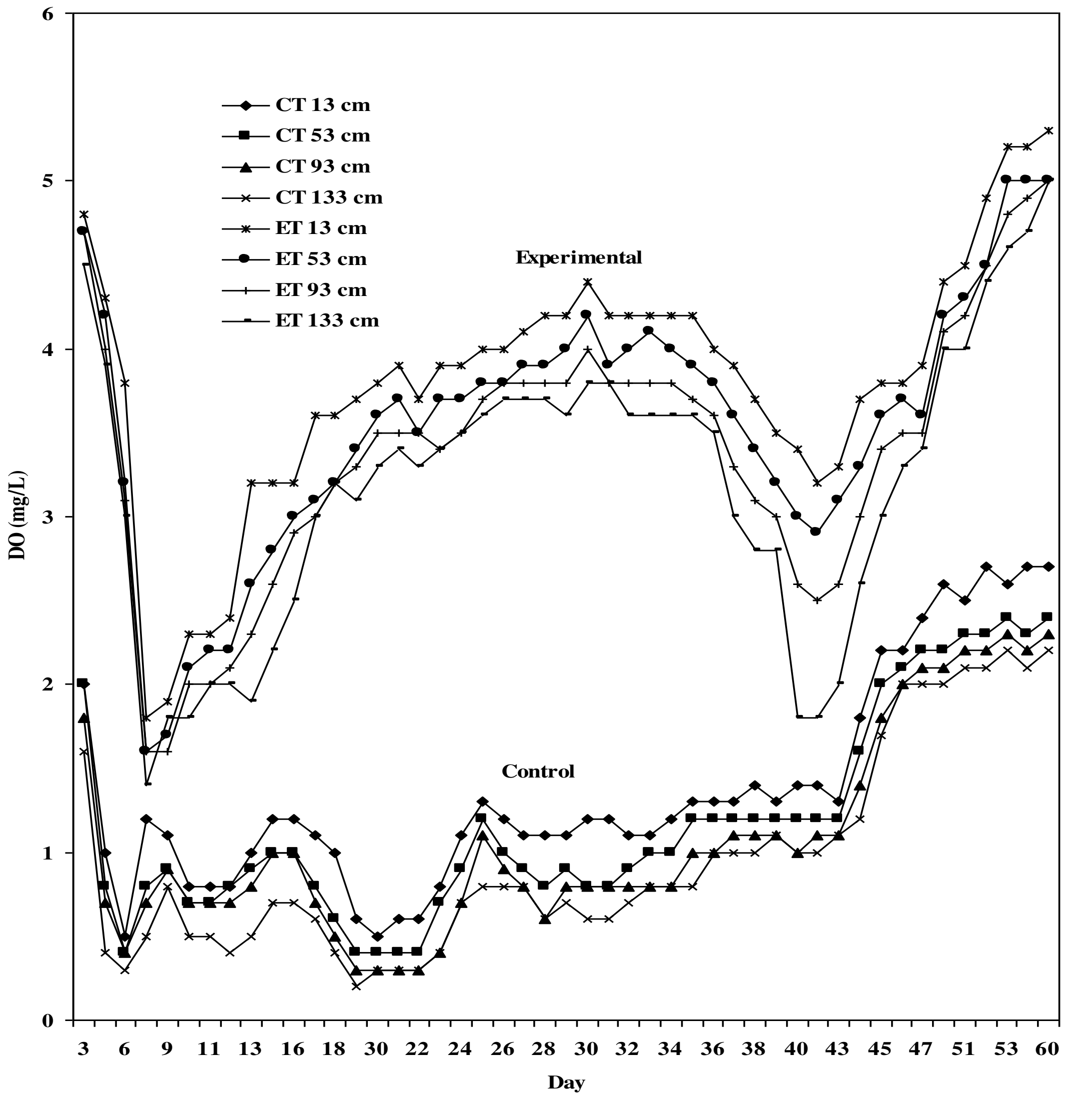

Figure-1. Comparative DO profile of the control and experimental tank filled with 1178 L lake Harapan water and the experimental tank was dosed with 706.8 ml of peat coagulant and left for settling till the end of the study. (1 ml peat coagulant = 39.5 mg.)

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3.2 Chemical oxygen demand (COD)

COD monitoring of the CT for several weeks revealed that there was not much difference of COD at different depths for the first few days. However, after the first week, there was a sudden increase of COD at the bottom point (Figure-2). This was due to the degradation of the algae, which settled at the bottom. . Sometimes excessive productivity of the algae causes death of the algae and the subsequent decomposition process utilises the dissolved oxygen of the aquatic system resulting lower dissolved oxygen content (Manahan, 1994). A similar phenomenon was observed as shown in the DO monitoring profile for this experiment where the DO level of the bottom point of CT reached as low as 0.8 mg/L. In fact, the COD value reached as high as 624 mg/L. Generally the breakdown products of algae were highly organic like glycolic acid, polysaccharides and low molecular weight sugars, trace amount of complex macromolecular carbohydrates, organic acids, amino acids and lipids (Ellis, 1989). The additional organic loadings, due to the degradation of algae act as readily oxidisable organic matter, which contributes to a high COD value.

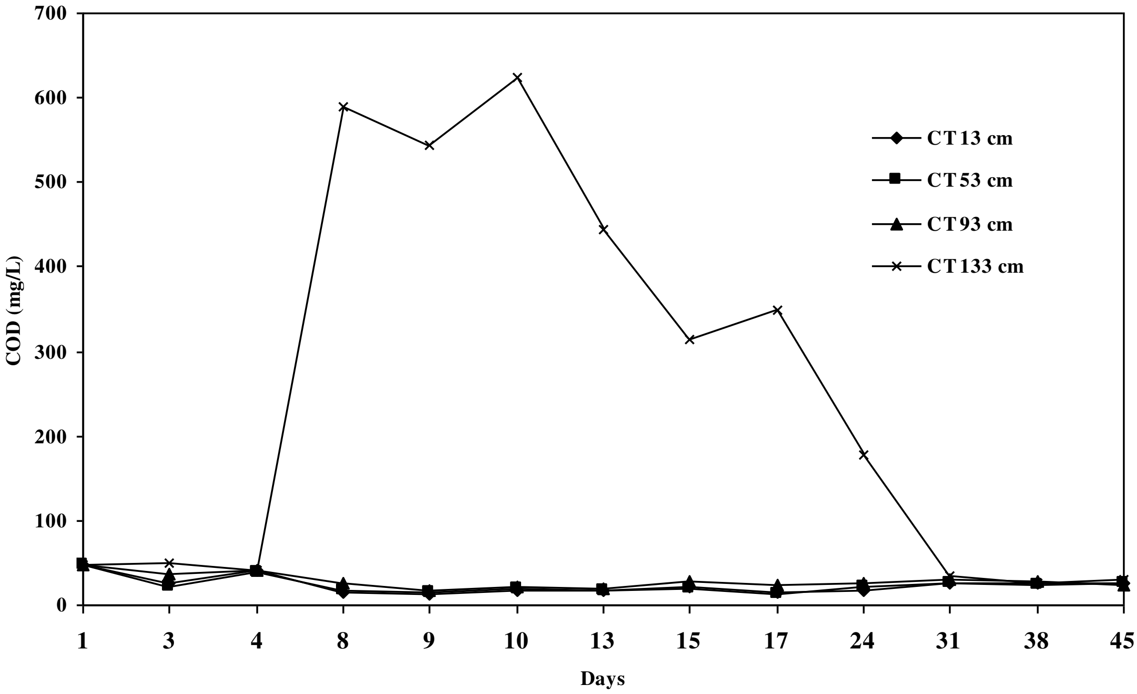

Figure-2. COD monitoring results at different depths of CT filled with 1178 L lake Harapan water and left for settling till the end of the study.

For ET, a reduction of COD values was observed at all points compared to the original COD. The highest COD value however was 21 mg/L. The lower COD values of ET compared to CT means less decomposition activity in ET. Moreover, its high DO content also reflected the lower consumption of oxygen for degradative oxidation. It should also be noted that 75 % of COD removal for ET tank (even at the bottom sampling point) was achieved within one week and remain at the same level through out the entire study period.

In Figure-3, the correlation of DO and the COD values at the bottom point (133 cm) of CT and ET is shown. The COD values correlate inversely with the DO values. It also revealed the fact that the DO increased with the decrease of COD. The higher COD value due to the accumulation of the biomass was responsible for the lower content of DO in CT.

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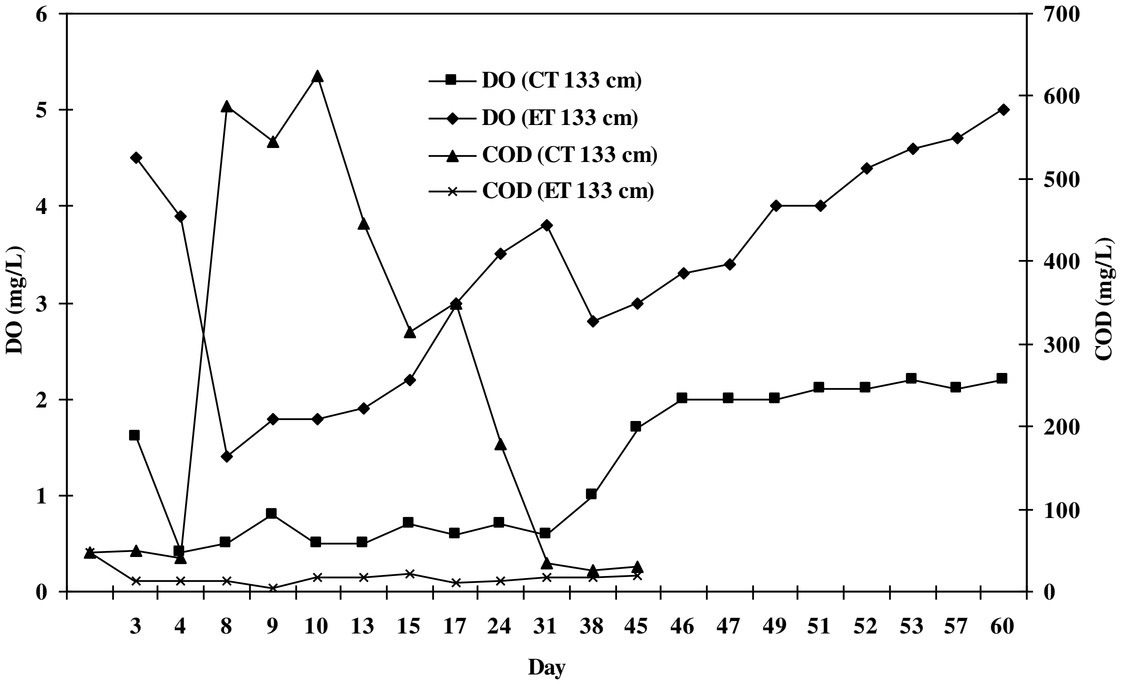

Figure-3. Comparative DO and COD profile of the bottom point (133 cm) of CT and ET for the whole study period.

3.3 Algae

Algae contents of the water at different depths were measured based on the total chlorophyll content of the water sample. For the lake water, it was found that the initial chlorophyll content was 3.47 mg/ml (2.69 mg/ml chlorophyll a and 0.78 mg/ml chlorophyll b). The chlorophyll content of ET shows minimal values due to the removal of significant amount of the biomass after treatment with peat coagulant. The focus was on profile of algae in the CT tank. On the third day, it was found that the chlorophyll content in the CT tank decreased at every point but increased at the bottom point (133cm) as shown in Figures 4 (a) & (b). Even though there was a continuous increase of the chlorophyll content at the bottom point, however at other points (13 cm, 53 cm and 93 cm) it was continuously decreasing and become zero after ten days. It could be assumed that all the algae settled towards the bottom of the tank. Therefore, for the bottom layer of the CT (133 cm), it was found that the algae concentration began to increase after the third day and reached its highest concentration of 40.47 mg/ml on the fourth day. Subsequently, it began to decrease gradually and after two weeks, the chlorophyll was not detected in the water sample collected from the bottom point.

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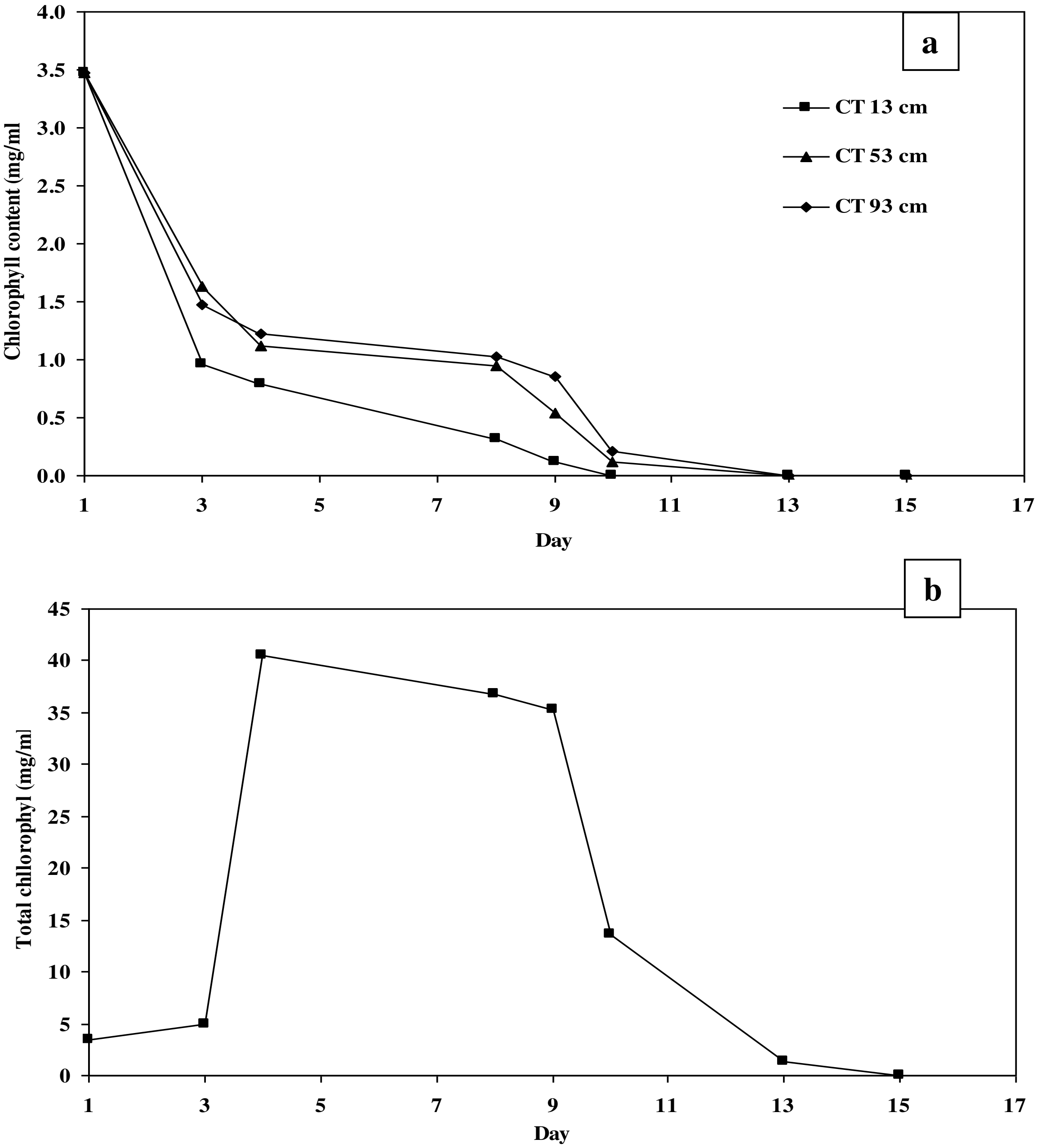

Figure-4. (a): Chlorophyll monitoring results of the upper 3 points of CT filled with 1178 L of Lake Harapan water and left for settling till the end of the study. (b): Chlorophyll monitoring results of the bottom (133 cm) point of the CT filled with 1178 L of Lake Harapan water and left for settling till the end of the study.

In Figures 5 (a) and (b), the correlation of chlorophyll content and the COD content of CT at different depths is shown. It is evident from the results that the main cause of COD was the degradation of algae, which was settled at the bottom. For the upper layers, the chlorophyll content was very low, i.e. 1.63 mg/ml. Therefore, the COD values at those points were not much affected due to the algae degradation. Whereas for the bottom point (133 cm), the algae concentration was very high as such on the fourth day, it was 40.47 mg/ml. A sharp increase of COD value on the eight day was observed and reached the maximum value of 624 mg/L on the tenth day. In conclusion, the cause of the high organic content in CT was due to the accumulation of the settled algae thus giving a high COD value and subsequently led to very low DO content due to the consumption of oxygen by degradation process of this accumulated algae.

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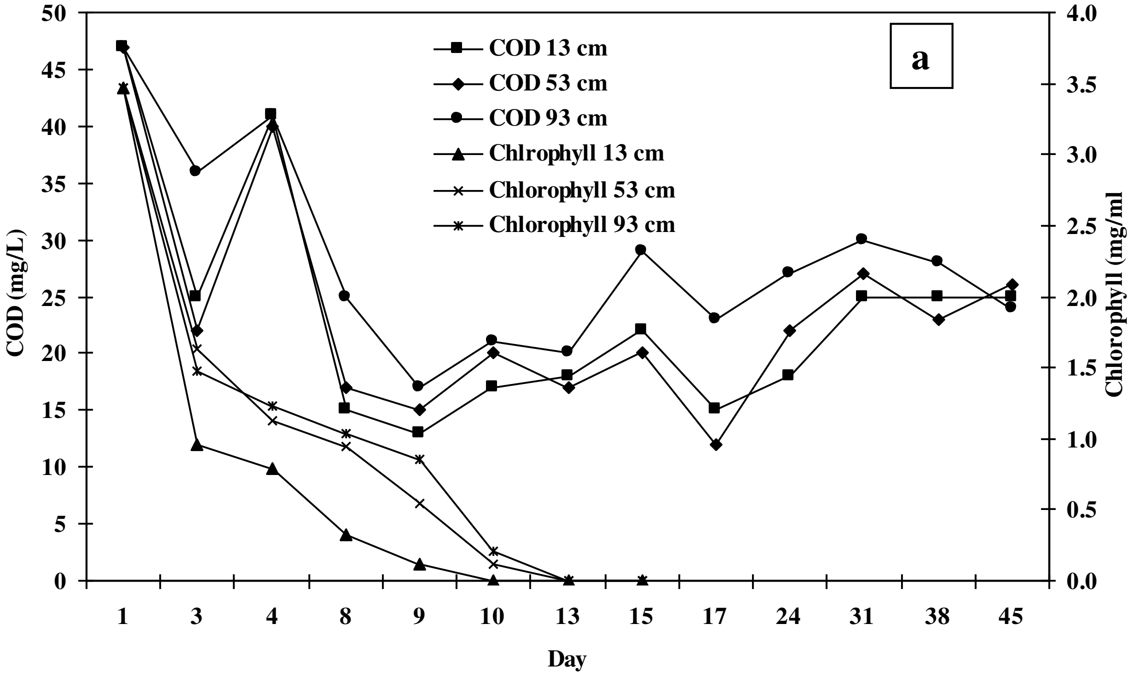

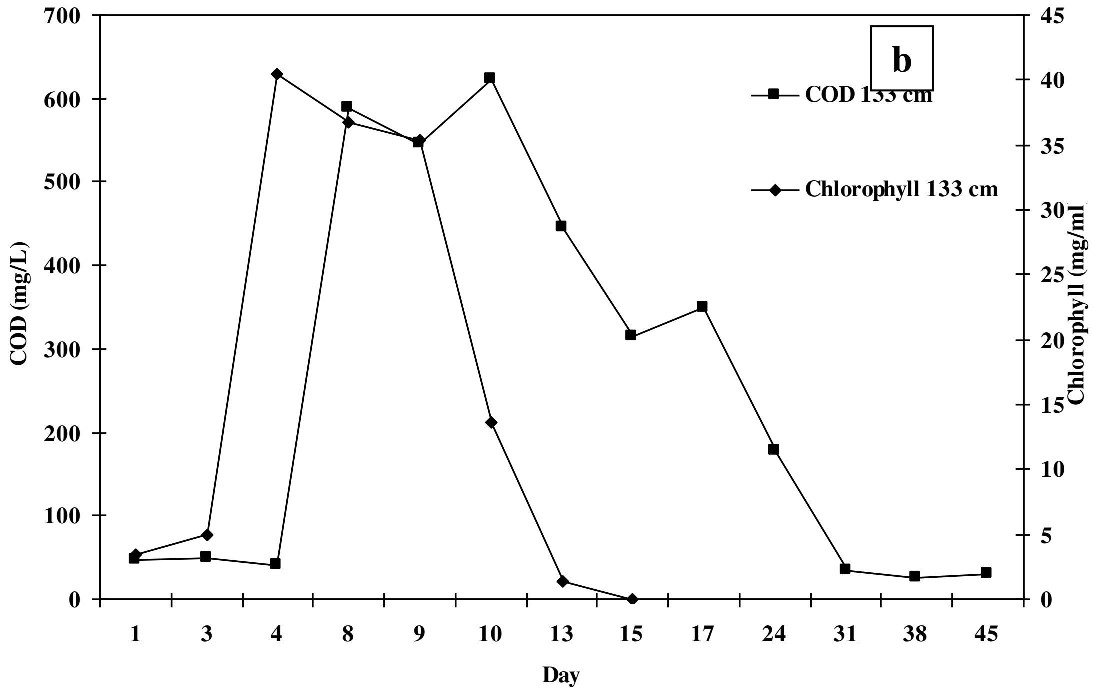

Figure-5. (a): Combined chlorophyll and COD content at different depths (13, 53, and 99 cm) of CT filled with 1178 L of lake Harapan water. (b): Combined chlorophyll and COD content at 133 cm depth of the control tank (CT) filled with 1178 L of lake Harapan water.

3.4 Turbidity (FTU)

The turbidity of lake water was caused mainly by the presence of colloidal algae and soil particles. The initial turbidity value was 65 FTU. CT showed a gradual decrease of turbidity with time. However after the second week, there was a sudden increase of turbidity to 447 FTU at the bottom point of the tank. This was due to the increase of algal content and the sedimentation process. The overall clarification of the water in CT took at least six weeks, whereby turbidity reached a value of 10 FTU and became stable at all sampling points of CT.

In contrast, after treatment of ET with peat coagulant, the turbidity immediately dropped to 14 FTU. This is equivalent to immediate clarification of the water by at least 78% at all levels of sampling points. ET showed a rapid decrease of turbidity and after the second week, it reached equilibrium in all sampling points with turbidity value less than 5 FTU. A similar level of clarification for CT required a much longer time, at least six weeks with terrible turbidity values at the bottom point occurring during this time period.

3.5 Nutrients (P and N)

The nutrient contents of water in both tanks apparently correlated well with the presence of algae and sedimentation process. In fact dead biomass or algae accumulates at the bottom of the lake where it partially decays and produces carbon dioxide, phosphorous, nitrogen and potassium (Manahan, 1994). It was reported that proper control of nutrients is the key elements for maintaining the lake environment (Schussler, *et al*., 2007; Jiang and Shen, 2006). There was a sudden increase of P concentration at the bottom point of CT. This sudden increase of P was due to the settling of suspended particles and colloids. Non-dissolved P was settled along with colloids at the bottom of CT and also from algae degradation. Algae present in abundance at the bottom of CT were one of the major sources of high phosphorus concentration at its bottom point. After third week, phosphorous concentration began to decrease and it reached equilibrium level over the sixth week.

For all the sampling points of ET, the phosphorous concentration was very low compared to the original concentration. There were not much changes of phosphorous concentration seen throughout the monitoring time at all points. Removal of phosphorous could be due to the settling of the suspended non dissolved phosphorous over the time.

Ammoniacal nitrogen, another potential nutrient for algal growth showed a higher concentration in the CT specifically at the bottom point. A similar trend as seen in phosphate values was noted here. This may also be due to the settling of algae at the bottom point of the tank. Usually ammonia nitrogen is formed from the degradation of biomass such as algae and other aquatic organisms.

Peat soil usually removes nutrients through adsorption (Ali, 2017; Malterer, 1996) and in this case application of peat coagulant caused the removal of nitrogen and phosphates from the lake water. The residual nitrogen in ET further went through oxidation process resulting in low residual ammonia nitrogen compared to CT due to the higher DO level in water. In the case of CT, the oxidation step was slower as the DO level was extremely low for certain period of time and the regain of DO was even slower compared to ET. In conclusion, the difference of nutrients condition in CT and ET shows the effectiveness of peat coagulant in the treatment of the lake water.

4. CONCLUSIONS

In this study, peat coagulant was applied for clarification of model water bodies. Optimum condition for the clarification of the model water bodies were via aeration technique of 15 minutes at a rate of 3-4 bar with 0.6 ml/L dosage of peat coagulant. It was found that peat coagulant effectively removed turbidity and lower down the COD and nutrients concentration. Due to the absence of the algae, there was no oxidative degradation occurring in the experimental tank, thus resulting in a lower nutrient content. Moreover, the DO level recovered in ET at a much faster rate than CT. The dissolved oxygen in CT reached the septic level for a long period of time and only began to recover gradually after seven weeks of observation. The main reason was due to the degradation of the settled algae. Therefore from this study it was found that peat coagulant was very effective for improving the water quality of water bodies by controlling the DO level, residual COD, turbidity, and lowering down the nutrient level. In addition, biodegradable nature of peat coagulant allows it to be used as an environmental friendly coagulant that could be applied in water and water bodies' treatment. Thus Peat coagulant can be a proper alternative for treating water bodies as compared to the usage of metal coagulants that could cause health and environmental hazards.

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