Canadian Journal of
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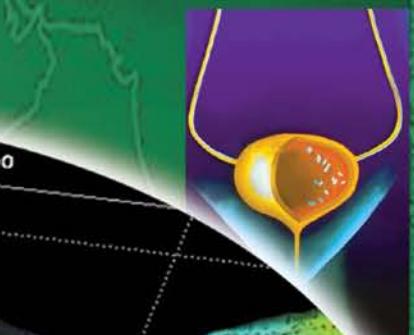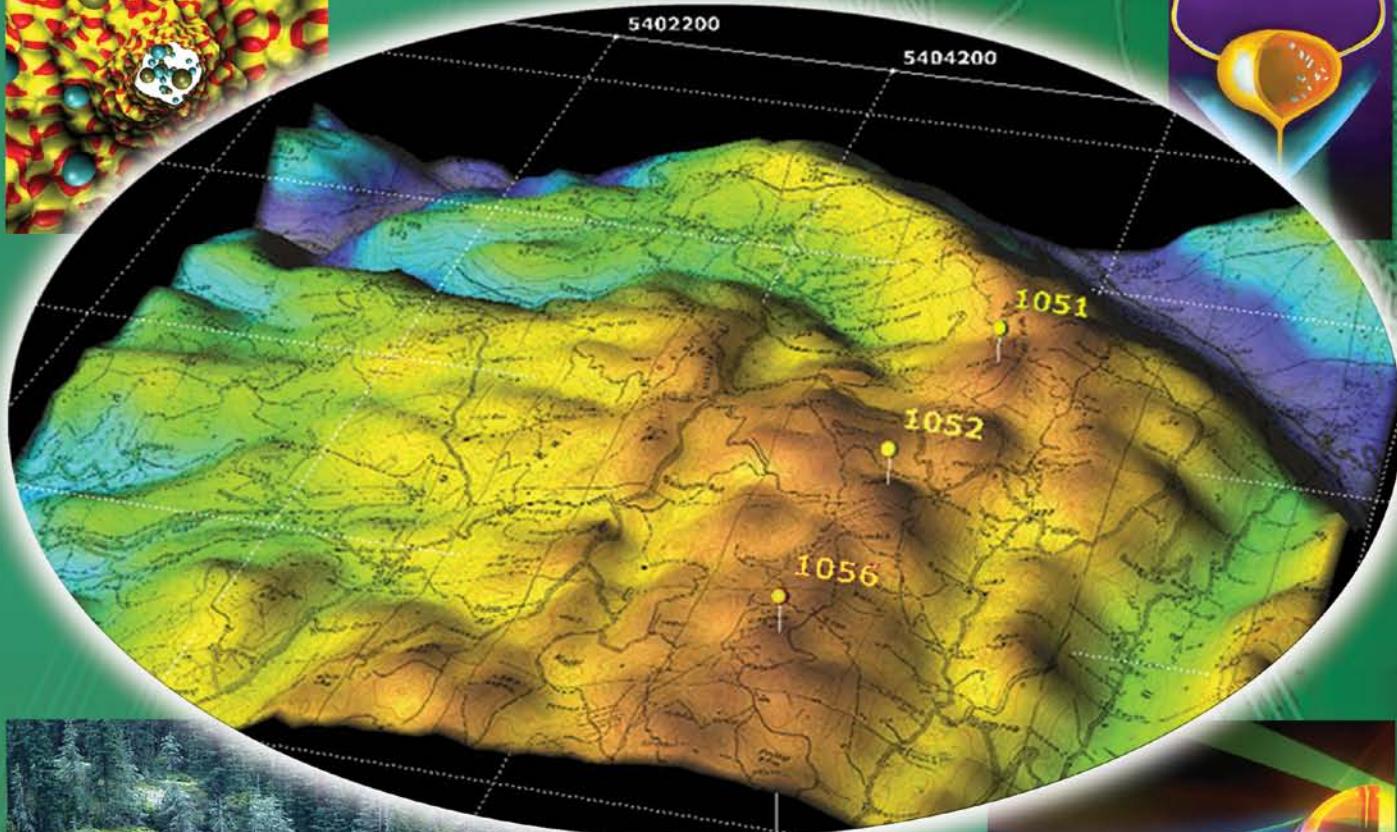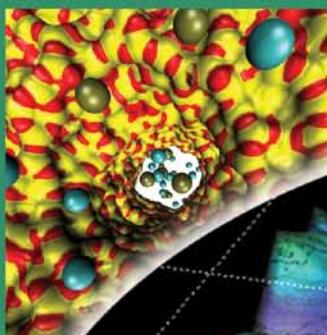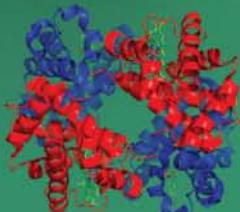
The Canadian Journal of Pure and Applied Sciences (CJPAS-ISSN 1715-9997) is a peer reviewed multi-disciplinary specialist journal aimed at promoting research worldwide in Agricultural Sciences, Biological Sciences, Chemical Sciences, Computer and Mathematical Sciences, Engineering, Environmental Sciences, Medicine and Physics (all subjects).

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Volume 2, Number 1
Jan 2008

CANADIAN JOURNAL OF PURE AND APPLIED SCIENCES

Board of Editorial Advisors

CLARIFICATION OF TURBID LAKE WATER
USING NOVEL COAGULANT FROM PEAT SOIL

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ABSTRACT

Malaysian peat soil usually categorised as tropical peat soil was chemically modified to work as a coagulant. This coagulant was found very effective for the removal of turbidity from lake and river water in a laboratory scale study. It was found that turbidity could be as low as 5 FTU after treatment with peat coagulant. Besides turbidity there was a reduction of suspended solids and chemical oxygen demand (COD) observed in this study. pH plays an important role for the clarification using peat coagulant. It was found that at acidic pH peat coagulant showed a better clarification compared to basic pH. It was mainly due to the chemical characteristics of the peat coagulant itself. The mechanism for the coagulation was suggested as charge adsorption neutralisation process. The effectiveness of peat coagulant was also compared with the commercial coagulant such as alum. Study revealed that the result obtained for different water quality parameters using alum as a coagulant was comparable with that of peat coagulant.

Keywords: Peat coagulant, lake water, turbidity, coagulation.

INTRODUCTION

Peat soil is abundantly available in many parts of the world. It is a naturally occurring polyelectrolyte, which is mainly the resultant of the decayed vegetation over a period of time (Shotyk, 1988). The process commences with the inhibited decomposition of trees and various plant species in the water logged environment of marshes, bogs and swamps. The vegetation is slowly oxidized by the micro-organisms to form peat (Spedding, 1988). It is organic in nature and the major components are humic acid, lignin and carbohydrates. The precise composition of peat formed depends on such factors as the nature of the vegetation, the regional climate, the acidity of the water and the degree of decomposition (Schnitzer and Gupta, 1965).

Application of peat soil for wastewater treatment had been widely investigated. The structure of polymeric humic acid has been provided by Stevenson (1982) showing numerous presence of carboxylic, phenolic and carbonyl functional groups. It is polar and highly porous material in addition to being inexpensive. Because of its polar characteristics, many elements such as metals and polar organic compound are adsorbed by peat under natural condition resulting in lower concentrations of these elements. These properties have consequently led to the examination of the potential of peat as an agent for the purification of water and wastewater with dissolved pollutants (Couillard, 1994). Compared to commercial ion exchanger, peat is comparatively inexpensive and easily available (Couillard, 1994). Another use of peat soil is as filter media. Its porous nature allows it to adsorb a wide number of pollutants mainly organic compounds (Poots *et al.,* 1976). Rock *et al*. (1984) and Brooks *et al.* (1984) used peat as a filter media for removal of COD and BOD (Biological Oxygen Demand) from the domestic sewage. Other area of research is the chemical modification or treatment of peat soil in order to introduce or increase the functional group for improved efficiency in wastewater treatment (Smith *et al.*, 1978; Dissanayake and Weerasooriya, 1981).

Malaysian peat soil categorised as tropical peat soil is different both chemically and structurally from the peat soil found in Europe and Canada. Agricultural use of tropical peat soil requires proper conditioning prior to use. Its use as fuel is also very limited. Even though use of temperate peat soil as filter medium was well studied (Couillard, 1994), this aspect of usage was rarely done for the tropical peat soil counterparts due to high leaching properties of their humic acid content. The severe leaching of the soil normally contributes high colour and often high COD (Chemical Oxygen Demand) in the effluent. It also has a low mechanical strength and a poor hydraulic conductivity (Mutalib *et al*., 1991).

One of the possible usage of tropical peat soil is to exploit its high humic acid content. Humic acid is essentially polyelectrolyte with carboxylic acid functional group that can be modified into functioning coagulant. Therefore, Malaysian peat soil which was rich in humic acid was

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modified into a functioning coagulant similar to the commercially available organic polymeric coagulant and was found to be effective for the removal of colloidal particles from turbid water samples (Mohd Asri *et al*., 2002; Mohd Asri and Zaidi, 2005). The effectiveness in removal of dyes from aqueous solution as well as textile waste water has also been reported (Helal Uddin, 2003; Helal Uddin *et al*., 2003). This work is mainly focused on the effectiveness of peat coagulant for the clarification of lake water and the mechanism involved. Different water quality parameters were monitored in order to justify the findings. The effectiveness of peat coagulant was also compared with the commercial coagulant alum.

MATERIALS AND METHODS

Peat soil: Peat soil samples were obtained from Batu Pahat area situated in the Johor State of Malaysia at a depth of not more than 1 meter. It was dark brown in color. They were then air dried for a few weeks on a flat tray. The soil was later ground into fine powder with the average particle size of 850 µm. Finally it was dried in oven at 180°C for 3-4 hours for further water removal. The properly dried soil was then stored in a dessicator prior to use.

Synthesis of Peat Coagulant: Peat coagulant was prepared following the procedure described by Mohd Asri *et al*. (2002) and Mohd Asri and Zaidi (2005). Accordingly, synthesis of peat coagulant was done by mixing properly dried raw peat soil powder with ethylenediamine using the ratio of 1 mL polyamine for every 1 g of peat and refluxing the mixture in a waterbath controlled at 80°C for at least 1 hour. The final product was purified by repeatedly dissolving it in water at pH 3.0 and precipitating it at pH 8.5. A 3.95% solution of peat coagulant was finally prepared by dissolving it in water at pH 3.0.

Lake Water Samples: Water samples were obtained from Lake Harapan situated in Universiti Sains Malaysia (USM), Penang, Malaysia. Samples were collected at different batches and different timings for studying different parameters. It was observed that turbidity and suspended solids vary with each batch of samples depending on the day and time of the sampling. This is understandable since turbidity arose mainly from soil particles and other colloidal materials due to the inflow of a small stream and also run-off from occasional rainfall. The turbidity would be the highest after a heavy rainfall (up to 400 FTU) and would be the lowest after weeks of dry periods. Sufficient standing time was given to obtain a consistent turbidity reading. For the dosage turbidity relationship study, the samples with varying turbidity were obtained by taking water samples at different time within the study period. No adjustment of the characteristics of the lake water was done prior to the

study. Samples were used immediately after it had been collected from the lake.

Alum: Alum [$Al_2(SO_4)_3.16H_2O$] analytical grade was obtained from Fluka. For turbidity and Chemical Oxygen Demand (COD) determination, the HACH (1982) method was adopted. All other chemical and reagents used in this study were of analytical grades. 3.95% and 10% solutions of peat coagulant and alum respectively were used in this study.

Laboratory Jar Test: Jar test for the lake water using different coagulant was performed using six paddle mechanical flocullator from Stuart Scientific UK. This flocculator allows up to six individual tests to be run simultaneously. The jar test has a variable speed motor that allows control of the mixing in the jar. To disperse the coagulant in the water sample, fast stirring for a short time (1 min. @ 200 rpm) was performed prior to moderate mixing at a slower speed (30 min. @ 60 rpm) for a longer duration to facilitate the larger flock formation. Sampling of the coagulated water was done after the flocks were settled completely (20 min.), without disturbing the settled sludge. Fast and slow mixing time and settling time were standardized and maintained throughout the study. pH adjustment was done by addition of dilute HCl or NaOH solutions. 250 mL lake water sample was used for the jar test. In order to obtain the optimum dosage for water sample with different turbidity, a series of 250 mL of lake water sample were used for jar test study with addition of peat coagulant in increasing manner. The dosage that produces the lowest turbidity value was identified as the optimum dosage value for that particular batch of lake water sample. Turbidity measurement was done using HACH DR/2000 spectrophotometer. All the dosage and pH study results are the average of three independent reading and reported with standard deviation.

RESULTS AND DISCUSSIONS

Peat soil is a natural inexpensive material rich in humic substances. In Malaysia, it is present in abundance and covering almost 8% of the total land area (Mutalib *et al*., 1991). Due to the tropical climate, the decomposition and deposition systems result in different characteristics of this peat. It has a very high organic content (up to 90%) and the ash content varies from 20% to 60%. Their water retention capability and mechanical activity are very poor. This type of peat has a high carbon-nitrogen ratio with an acidity of pH 3.5. Almost 32% of the total peat land in Malaysia is utilised for agricultural usage. However, this peat is generally considered as a problem soil for vegetation because of their poor nutrient content with acidic nature (Mutalib *et al*., 1991). In our effort to expand value-added products of tropical peat soils, peat coagulant was prepared using tropical peat soil of

Malaysia. Peat coagulant is a chemically modified product of humic acid rich tropical peat soil. The characterisation of the peat coagulant revealed that phenolic and carboxylic groups within the peat soil were utilized for the attachment of the ethylenediamine enabling it to function as a coagulant (Mohd Asri *et al.*, 2002; Mohd Asri and Zaidi, 2005; Helal Uddin, 2003; Helal Uddin *et al.*, 2003).
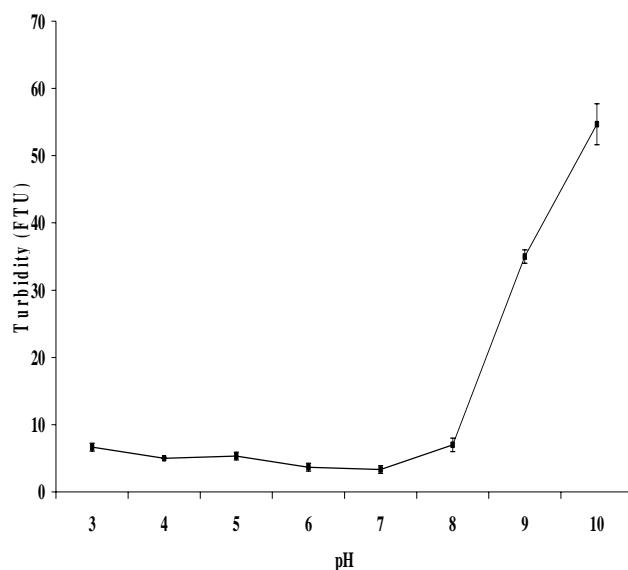

Fig. 1. pH study of the PC for the clarification of the lake water. (1mL PC = 39.5 mg) (Mean ± S.D, n =3)

The analysis result for the peat coagulant is shown in Table 1. It shows that peat coagulant is highly organic (94 %). Small amount of metal ions were also found in peat coagulant namely iron, zinc, aluminium, copper etc. The presence of the metal ions in peat coagulant probably arises from the clay component of peat soil from which the peat coagulant was prepared (Helal Uddin, 2003). Further more peat soil also contains some bounded metal with its functional group rich components like humic acid and lignin (Clara, 1985).

Table 1: Characteristics of peat coagulant.

Parameter	Peat Coagulant
pH	2.95-3.15
Weight (gm)	1.033
Total Solid (%, *w/w*)	3.95
Organic (%)	94.3

pH and dosage study for the peat coagulant were performed by jar test method describe earlier in the materials and methods section. The results of the clarification of the lake water using peat coagulant at different pH are shown in Fig. 1. It is apparent from the graph that a good removal of turbidity was achieved in the pH range of 3 to 8. As the pH increases towards more alkaline value the removal becomes poorer. Removal of

turbidity becomes essentially zero at pH above 8. The poor performance of peat coagulant within alkaline pH may be due to the nature of the peat coagulant itself. It was reported that peat coagulant had been inserted with amino functional group (Mohd Asri *et al.*, 2002, Mohd Asri and Zaidi, 2005). These groups in peat coagulant are protonated under acidic pH, which means its positive charges increased at low pH values. Generally cationic polyelectrolytes are amines or poly amines and due to the increase of positive charges they are more effective at a lower pH. As the pH increases they approach the neutral state (Kemmer, 1988). In water treatment plant, usually coagulants with selective pH range are not very widely used as the chances of sudden change of pH might cause a severe effect on the whole process (Amirtharajah and O'Melia, 1990). In that respect, peat coagulant would be a better choice as its pH tolerance is wider covering acidic, neutral and slightly alkaline pH. Turbidity of the lake water was mainly due to the inorganic suspended particles and peat coagulant shows a better performance at lower pH range. But at higher pH range i.e. beyond pH 8 the turbidity increases due to the charge reversal phenomenon (Benefield *et al.*, 1982). Within this alkaline region, not only the particles from the lake water but also the particles from peat coagulant itself contribute to the colloidal system reestablishment which eventually increases the turbidity.
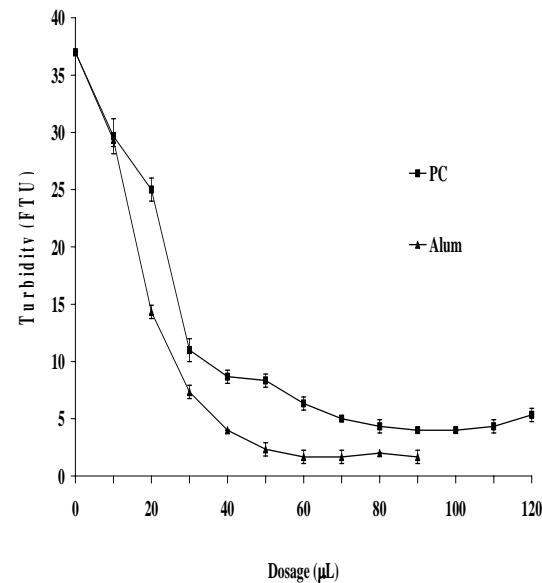
Fig. 2. Dosage study of the different coagulant for the clarification of the lake water. (1mL PC = 39.5 mg; 1mL Alum = 100 mg.) (Mean ± S.D, n =3)

Fig. 2 shows the effect of coagulant dosages (PC and alum) in the clarification of lake water. The initial turbidity of the lake water sample was 37 FTU and with the increase of the dosage, a substantial amount of turbidity removal was observed for both coagulants. It was found that peat coagulant with a dosage of 80 μL

showed maximum clarification of 90%, whereas with 60 μL dosage, alum showed a 94% turbidity removal. There was a sharp decrease in turbidity with the increase of the coagulants dosages observed at the beginning of the clarification process. After the optimum level of clarification was reached, the effectiveness was maintained with the increase of the dosage. However, after 110 μL of dosage, the turbidity began to increase again suggesting that occurrence of charge reversal phenomenon of peat coagulant. This charge reversal phenomenon was also observed when peat coagulant was used for the removal of dye solution (Helal Uddin *et al.*, 2003).
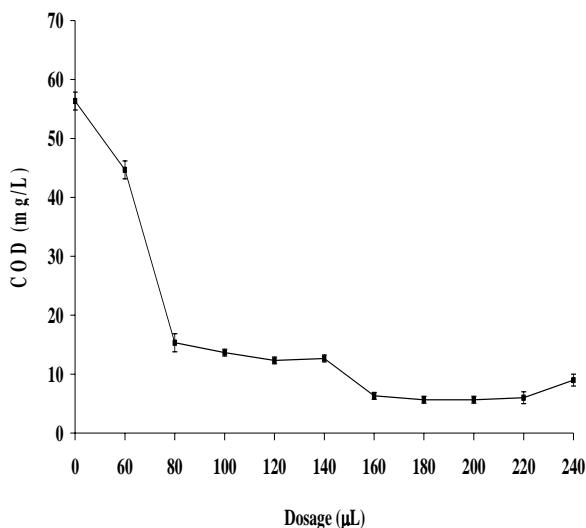
Fig. 3. COD values of the PC treated lake water. (1 mL PC = 39.5 mg) (Mean ± S.D, n =3)

Lake water samples used in this study contained organics matter that was reflected in chemical oxygen demand values (COD, ~57 mg/L). Usually COD results from the total organic content in the water both in dissolved or suspended forms. There was a removal of COD values with the clarification of the turbidity from the lake water when it was treated with peat coagulant. The decrease of COD values with the increment of the peat coagulant dosage is shown in Fig. 3. Similarities between turbidity removal and COD removal were observed in this study. Due to the removal of the turbidity, the colloidal particles were settled as flocs and there was possible enmeshment of other dissolved substances that might result in the decrease of the COD values of the treated lake water. This observation is interesting since peat coagulant was a product developed from tropical peat soil that is well known with organic leaching. Analysis results showed that peat coagulant prepared from this soil is 94% organic substances. Even though tropical peat soil has a characteristic of high organic leaching (Mutalib *et al.*, 1991) apparently when it is converted to peat coagulant there is no proof of leaching observed from the COD

study. This is understandable since in direct contrast to humic acid that begins to dissolve at alkaline pH, peat coagulant solubility decreases with increasing pH. It precipitates well under alkaline condition with optimum pH at 8.5. For this reason, purification of peat coagulant was done at pH 8.5 where it precipitated from water (Mohd Asri *et al.*, 2002; Mohd Asri and Zaidi, 2005). Within this study, the optimum dosage of the coagulant was between 12.64 mg-15.8 mg for every liter of water sample with turbidity of 37 FTU. Since the dosage was quite minute amount and the residual excess of coagulant was also expected to precipitate and became enmeshed with coagulated particles, the contribution of COD by the coagulant would be very negligible. This study therefore establishes the fact that even though peat coagulant is highly organic in nature, it does not seem to contribute to the increase of the COD level of the sample but rather was quite effective not only in removal of turbidity but also in removal of the COD values.
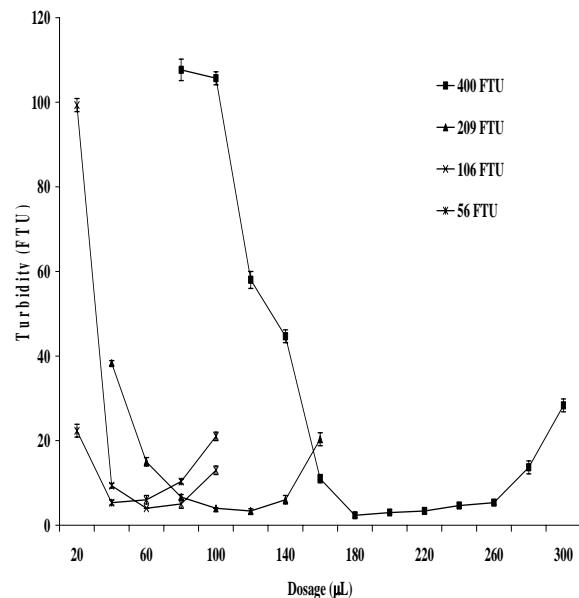
Fig. 4. Optimum dosage study of PC for clarification of lake water having different turbidity. (1 mL PC = 39.5 mg) (Mean ± S.D, n =3)

The lake water samples with different turbidity were collected during different time of the study as mentioned in the methods section and no prior adjustment were made to standardise the turbidity. Within the period of this study, the turbidity of the lake water samples varies from 37 FTU to as high as 400 FTU. The reason for this variation in turbidity was stated previously in the method section. In Fig. 4, the results of the dosage study of peat coagulant for the clarification of lake water with different turbidities are illustrated. There was a shift of the optimum value in increasing manner with the increase of the turbidity of the lake water. It is understood that the optimum dosage required to achieve the maximum clarity level (lower FTU value) is not the same for the sample
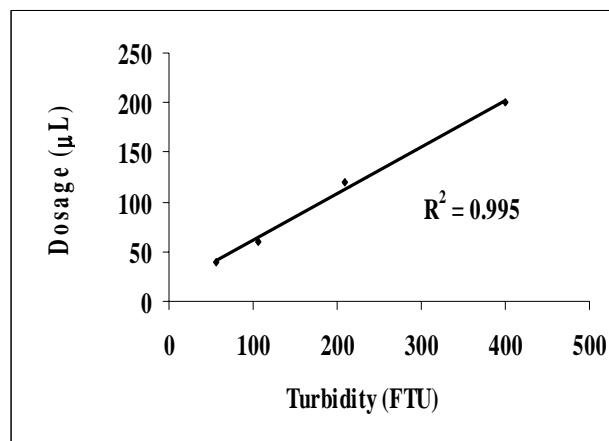
Fig. 5. Relationship between the optimum dosage and turbidity.

Table 2. Typical water quality results for the lake water before and after the coagulation with different coagulants.

Parameters	Untreated Lake Water	PC Treated Lake Water	Alum Treated Lake Water
Turbidity (FTU) (mg/L)	65	5	2
Suspended Solids (mg/L)	36	1	1
Chemical Oxygen Demand (COD) (mg/L)	47	6	5
pH	7.4	6.8	5.2

with different turbidity. In this study the dosage amount of peat coagulant required to obtain the lowest turbidity was identified as optimum dosage for that particular batch of the lake water. From Fig. 4 we can find that the optimum dosage obtained for the turbidity of 56, 106, 209 and 400 FTU were 40, 60, 120 and 200 µL respectively. These two series of values obtained from Fig.4 shows a linear correlation between the optimum dosage and the turbidity of the lake water. In Fig. 5 the correlation of the apparent optimum dosage and the turbidity of the different lake water samples is shown where linearity is observed between the two parameters.

According to Benefield *et al*. (1982), when coagulation of water follows adsorption-charge neutralisation mechanism, a plot of turbidity versus optimum dosage shows linear relation. For peat coagulant, a linear correlation was obtained suggesting that coagulation mechanism occurred via adsorption-charge neutralisation process. In Fig. 4, it was also observed that after addition of the peat coagulant beyond the optimum dosage, the turbidity of the water sample started to increase while its clarity decreased. As mentioned earlier, this is an indication that a charge reversal phenomenon had occurred with peat coagulant system. In this case, excess dosage of coagulant had completely changed the coagulated colloidal particles into positively charged species and start to repel each other and restabilize again. Since a charge reversal or re-establishment of the colloidal stability was observed, it further supports our claim that the mechanism of coagulation with peat coagulant was based on adsorption -charge neutralisation process. A typical water quality result for the lake water before and after the peat coagulant and alum treatment is given in Table 2. These results further confirmed that peat coagulant works as effective as alum for treating lake water.

CONCLUSIONS

This work support that peat soil can be utilised as coagulant material for the removal of turbidity from lake water and the mechanism followed is adsorption charge neutralisation. It was also observed that the peat coagulant treated lake water has lower COD values, which is an important water quality parameter for water treatment system. This study therefore establishes the fact that even though peat coagulant is highly organic in nature, it did not contribute to the increase of the COD level of the sample. Overall, the performance of peat coagulant for the clarification of lake water was comparable to alum. Moreover, it has the advantage of having possibilities of low residual aluminum content and the ability to maintain the pH at neutral level as compare to alum treatment. Finally, peat coagulant also had the advantage of wide pH working range.

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