Peat Water Treatment Using Combination of Cationic Surfactant Modified Zeolite, Granular Activated Carbon, and Limestone

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Abstract

This research was conducted essentially to treat fresh peat water using a series of adsorbents. Initially, the characterization of peat water was determined and five parameters, including pH, colour, COD, turbidity, and iron ion exhibited values that exceeded the water standard limit. There were two factors influencing the adsorption capacity such as pH, and adsorbent dosages that were observed in the batch study. The results obtained indicated that the majority of the adsorbents were very efficient in removing colour, COD, turbidity at pH range 2-4 and Fe at pH range 6-8. The optimum dosage of cationic surfactant modified zeolite (CSMZ) was found around 2 g while granular activated carbon (GAC) was exhibited at 2.5 g. In column study, serial sequence of CSMZ, GAC, and limestone showed that the optimal reduction on the 48 hours treatment were found pH = 7.78, colour = 12 TCU, turbidity = 0.23 NTU, COD = 0 mg/L, and Fe= 0.11 mg/L. Freundlich isotherm model was obtained for the best description on the adsorption mechanisms of all adsorbents.

Keywords: cationic surfactant modified zeolite, granular activated carbon, limestone, peat water

1. Introduction

Water is essential and fundamental to all living forms and is spread over 70.9% of the earth's surface. However, only 3% of the earth's water is found as freshwater, of which 97% is in ice caps, glaciers and ground water (Bhatmagar & Minocha, 2006). In Malaysia, more than 90% of fresh water supply comes from rivers and streams. The demand for residential and industrial water supply has grown rapidly coupled with an increase in population and urban growth (WWF Malaysia, 2004). Water demand in affected populations such as rural areas also demands that attention is paid to providing more sustainable solutions rather than transporting bottled water (Loo et al., 2012). For this reason, it is essential to ensure availability of local sources of water supply and even develop new potential sources of water such as from peat swamp forest to overcome future water shortages.

River water surrounded by peat swamp forest is defined as peat water and is commonly available as freshwater since it has a low concentration of salinity. The previous study shows that peat swamp forest has high levels of acidity and organic material depending on its region and vegetation types (Huling et al., 2001). Under natural conditions, tropical peat lands serve as reservoirs of fresh water, moderate water levels, reduce storm-flow and maintain river flows, even in the dry season, and they buffer against saltwater intrusion (Wosten et al., 2008).

Due to the acidity and high concentration of organic material, selective treatment of peat water must be conducted prior to its use as water supply. Recently, many methods have been designed and have proven their effectiveness in treating raw water such as coagulation and flocculation (Franceschi et al., 2002; Liu et al., 2011; Syafalni et al., 2012a), absorption (Ćurković et al., 1997), filtration (Paune et al., 1998) and combining (Hidaka et al., 2003). Careful consideration of the most suitable method is important to ensure that the adsorption process is the most beneficial, economically feasible method as well as easy to operate for producing high quality of water in a particular location.

Many researchers have shown that activated carbon is an effective adsorbent for treating water with high concentrations of organic compounds (Eltekova et al., 2000; Syafalni et al., 2012b). Its usefulness derives mainly from its large micropore and mesopore volumes and the resulting high surface area (Fu & Wang, 2011). However, its high initial cost makes it less economically viable as an adsorbent. Low cost adsorbent such as zeolite nowadays has been explored for its ability in many fields especially in water treatment. Natural zeolite has negative surface

charge which gives advantages in absorbing unwanted positive ions in water such heavy metal. These ions and water molecules can move within the large cavities allowing ionic exchange and reversible rehydration (Jamil et al., 2010). The effectiveness of zeolite has been improvised by modified zeolite with surfactant in order to achieve higher performance in removing organic matter (Li & Bowman, 2001). Among tested cationic surfactants, hexa-decyl-tri-methyl ammonium (HDTMA) ions adsorbed onto adsorbent surfaces are particularly useful for altering the surface charge from negative to positive (Chao & Chen, 2012). Surfactant modified zeolite has been shown to be an effective adsorbent for multiple types of contaminants (Zhaohu et al., 1999).

Zeolite is modified to improve its capability of exchanging the anion by cationic surfactants, called CSMZ. CSMZ adsorbs all major classes of water contaminants (anions, cations, organics and pathogens), thus making it reliable for a variety of water treatment applications (Bowman, 2003). Nowadays, interest in the adsorption of anions and neutral molecules by surfactant modified zeolite has increased (Zhang et al., 2002). Modification of zeolite by surfactant is commonly done by cationic or amphoteric surfactants. By introducing surfactant to the zeolite, an organic layer is developed on the external surfaces and the charge is reversed to positive (Li et al., 1998). However, the present study used zeolite that had been modified using Uniquat (QAC-50) as cationic surfactant (CSMZ) and their performance towards the removal of color, COD, turbidity and iron ion from peat water were investigated.

2. Materials

Four adsorbents were used in these experiments which are natural zeolite, zeolite modified by cationic surfactant, activated carbon and limestone. All adsorbents were prepared with equivalent sizes of 1.18 mm - 2.00 mm. Hydrochloric acid (HCl) and sodium hydroxide (NaOH) were used for polishing zeolite during the preparation phase and for pH adjustment of the sample. Furthermore, potassium dichromate (K_2CrO_7), silver sulphate (Ag_2SO_4), sulphuric acid (H_2SO_4) and mercury (II) sulphate ($HgSO_4$) were used as digestion solution reagents and acid reagents for COD analysis. Lastly, Uniquat (QAC-50) was used as cationic surfactant to modify the zeolite.

2.1 Preparation of Surfactant Modified Zeolite

In these studies, 100 g of prewashed natural zeolite was contacted with 5.6 ml/l Uniquat (QAC-50) as cationic surfactant (CSMZ). The mixture was then stirred at room temperature for 4 hours at 300 rpm (Karadag et al., 2007). The zeolite then was filtered and washed with distilled water several times. After that, the absorbent was dried in an oven at a temperature of 105 °C for 15 hours.

2.2 Test Procedures

2.2.1 Batch Studies

Serial batch studies were conducted at room temperature (28 ± 1 °C) to investigate the influence of pH and dosage for removing colour, COD, turbidity and iron ion from peat water. Shaking speed of 200 rpm for 20 minutes were fixed and operated respectively. A working volume of 150ml peat water sample was set up in 250 ml conical flasks. Preceding the batch studies, initial concentration for those parameters was determined. The optimum pH and dosage of absorbent were determined. Subsequently, the percentage of removal was finally determined, plotted, and compared.

2.2.2 Batch Column Studies

Column studies were carried out using a plastic column with dimensions: 5.4 cm diameter and 48 cm length. Three adsorbents were filled inside the column at a specific depth with the supporting layers of marbles, cotton wool, and perforated net. Total volume of 2000 ml peat water was pumped in the up flow mode from the vessel into the column by using a Masterflex peristaltic pump at a minimum flow rate of (30, 60, 90) ml/min. In this study, however, column studies were performed un-continuously (batch) due to limitations of time. All parameters related to the column design are summarized in the following Table 1.

Table 1. Column studies parameters

Parameters	Unit	Value
Diameter, D	cm	5.4
Horizontal Surface Area, A	cm^2	22.9
Column volume, V	cm^3	1099.3
Flowrate, Q	ml/min	30, 60, 90
Surface Loading Rate, SLR= Q/A	cm/min	1.31, 2.62, 3.93

The serial sequence arrangements of adsorbents were conducted as shown in Figure 1 below. Effluent samples were collected at various time intervals, whilst maintaining room temperature, and analysed.
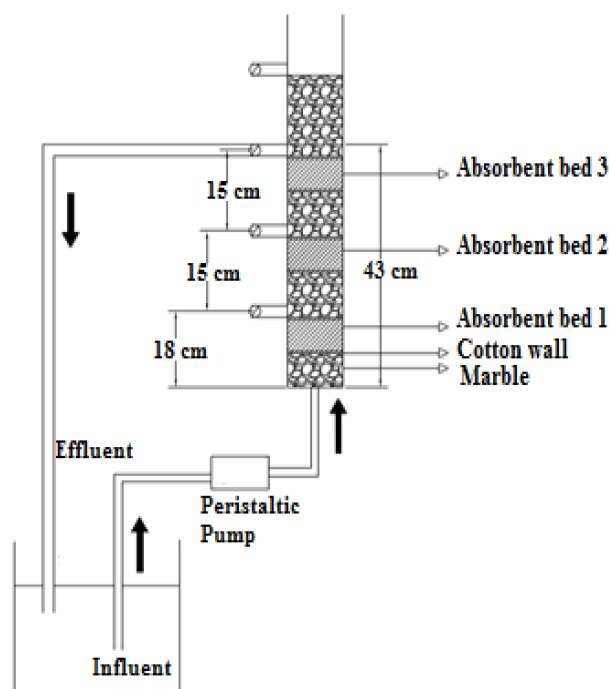
Figure 1. Schematic diagrams of lab-scale column studies

3. Results and Discussion

3.1 Peat Water Characterization

Surface water originating from the peat swamp forest was taken from Beriah peat swamp river along the Kerian River on several occasions as the main sample. The characterization of peat water was carried out at the sampling point (in-situ measurement) using a multi-parameter probe as well as in the environmental laboratory of civil engineering, USM. Fundamentally, the characterization procedures were based on the Standard Methods for the Examination of Water and Wastewater (APHA, 1992). Table 2 represents the peat water characteristics in average value and the comparison to the standard drinking water quality in Malaysia.

Table 2. The characteristics of peat water sample from Beriah Peat Swamp Forest

Parameters	Unit	Average Value
pH	-	4.67 - 4.98
Temperature	°C	27.8
TDS	mg/L	20.6
DO	mg/L	3.4
Conductivity	uS/cm	34.5
Salinity	Ppt	0.02
Color	TCU	224.7
Turbidity	NTU	20.8
COD	mg/L	33.3
Iron, (Fe)	mg/L	1.24
NH_3-N	mg/L	0.51

Thirteen parameters were successfully determined where the first six parameters, including pH, temperature, TDS, DO, conductivity, and salinity were measured at the sampling point, whilst the rest of the parameters, including colour, turbidity, COD, iron ion, Ammoniacal Nitrogen, NH_3-N, Ammonia (NH_3), and Ammonium ($NH4^+$) were examined from the sample brought to the environmental laboratory on the same day.

Acidic pH of the peat water was predicted due to the composition of the surrounding peat soil itself which had been formed by decaying material possessing humic substances (Rieley, 1992). Besides that, humic substances also lead to the high organic content as humic substances are comprised of numerous oxygen containing functional group and fractions (humic acid, fulvic acids and humin) with different molecular weights which mean yielding high concentration of turbidity and COD as well as coloured water (Torresday et al., 1996). Moreover, composition of peat soil may also have an impact on the iron ion concentration of peat water (Botero et al., 2010).

From the thirteen parameters, five parameters were indicated exceeding the standard limit. These parameters were pH, colour, turbidity, COD, and iron ion that showed values of 4.67 - 4.98, 224.7 TCU, 20.8 NTU, 33.3 mg/l, and 1.24 mg/l respectively while the standard limit of these parameters are 6.5 - 9.0, 15 TCU, 5 NTU, 10 mg/l, and 0.3 mg/l accordingly.

3.2 Effect of Initial pH on the Efficiency of Colour, COD, Turbidity, and Iron Ion (Fe) Removal

Influence of initial pH on the adsorption capacity for removing colour, COD, turbidity, and iron ion were investigated.

Figure 2(a) to Figure 2(d) below, displayed the percentage removal of colour, COD, turbidity, and iron ion against pH of adsorbents respectively.
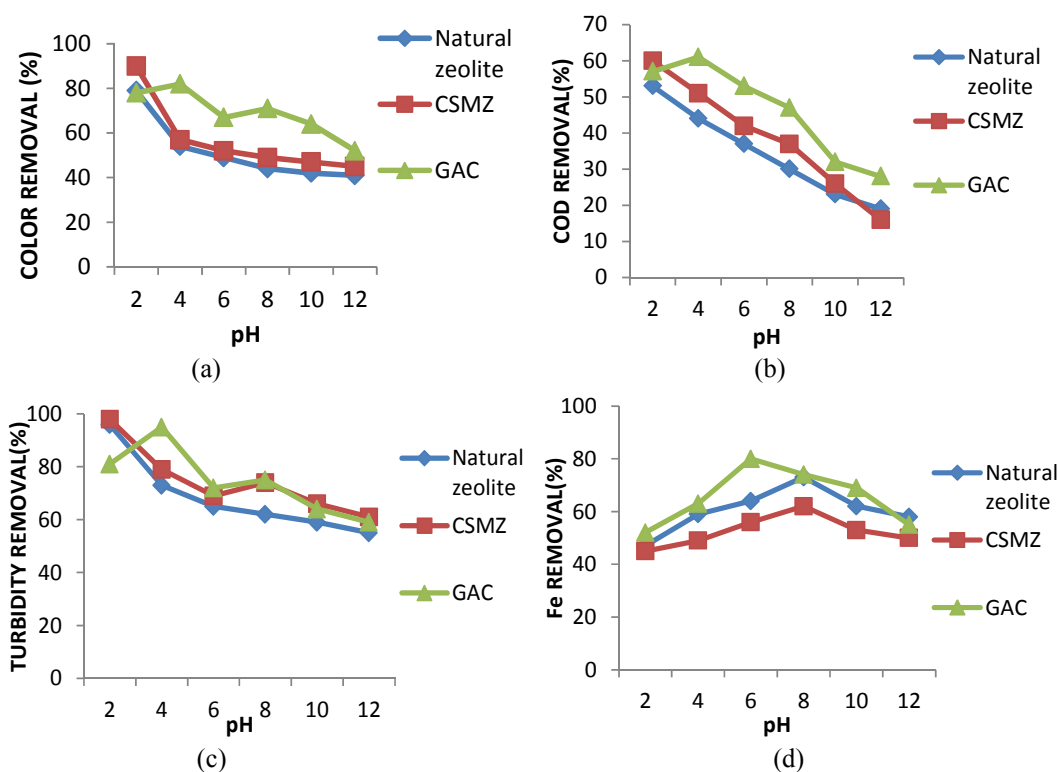
Figure 2. Percentage of color (a), COD (b), turbidity (c), and Fe (d) removal (%) against pH for NZ, CSMZ, and GAC

Figure 2(a) shows the maximum removal percentage of colour that was removed by natural zeolite, CSMZ, and granular activated carbon (GAC) which were 79%, 90%, 82% respectively. This adsorption is depended on the characteristic of adsorbents itself. For zeolite and CSMZ were related to the amount of cationic ions (Al^{3+}) increased, resulting in high reaction activity and GAC was related to the adsorption capacity. It was observed that the adsorption capacity was highly dependent on the pH of the solution, and indicated that the colour removal efficiencies decreased with the increase of solution pH.

The pH of the system exerts profound influence on the adsorptive uptake of adsorbate molecules presumably due to its influence on the surface properties of the adsorbent and ionization or dissociation of the adsorbate molecule. Figure 2(b) represents the percentage removal of natural zeolite and CSMZ where they reach optimum efficiency in removing organic compound (COD) at pH 2 with efficiency of 53% and 60% respectively. Meanwhile, the highest percentage removal of COD for GAC was achieved at pH 4 with efficiency obtained about 61%. Identical trends in colour removal were exhibited in percentage removal of COD for natural zeolite, CSMZ and GAC. In fact, this result also reveals that GAC has the highest percentage removal among natural zeolite and CSMZ yet optimum in difference pH solution. Neutralization mechanism occurs in low pH makes color removal, COD removal and Turbidity removals at pH 2 are higher for most of absorbents in this process.

In Figure 2(c), percentage turbidity removal against pH for each adsorbent revealed that optimal reduction of turbidity was obtained in an acidic environment with efficiency removal of 96%, 98%, 95% for natural zeolite, CSMZ, and GAC respectively. When the pH of the solution was adjusted above pH 6 to pH 12, the tendencies of all adsorption performances were gradually decreased. Moreover, it also showed that the lowest efficiency for the three adsorbents were identified at pH 12 with percentage values removal 55%, 61%, and 59% for natural zeolite, CSMZ, and GAC respectively.

Figure 2(d) demonstrates the removal efficiencies of iron ion as a function of the influent pH. The maximum removal of iron ion was observed at pH 8 for both natural zeolite and CSMZ whereas GAC had its optimum removal at pH 6. Natural zeolite and CSMZ only yielded 73% and 62% removal efficiency while GAC had more significant removal with removal efficiency of 80% to the iron ion concentration. Further, it is evident from the graph that gradual increment of removal efficiency for natural zeolite, CSMZ, and GAC occurred when the initial pH of the solution was increased to higher values. Somehow, at pH values greater than 6 the removal efficiency of GAC reduced slightly while for natural zeolite and CSMZ the reduction occurred from pH values above 8.

3.3 Effect of Adsorbent Dosage on the Efficiency of Colour, COD, Turbidity, and Iron Ion (Fe) Removal

The effect of adsorbent dosage was studied for all adsorbents employed on colour, COD, turbidity, and iron ion removal by varying the dosage of adsorbent and keeping all other experimental conditions constant. The pH was set to acidic conditions which were most favourable in obtaining the highest removal efficiency. In this study, to find optimal adsorbent dosage of natural zeolite and CSMZ, the appropriate experiments were carried out at adsorbent dosages in the range of 0.5 g to 5.0 g while for GAC, the adsorbent dosage was varied from 0.01 g to 4.0 g. The experimental results for all the adsorbents are represented by Figure 3(a) to Figure 4(d).
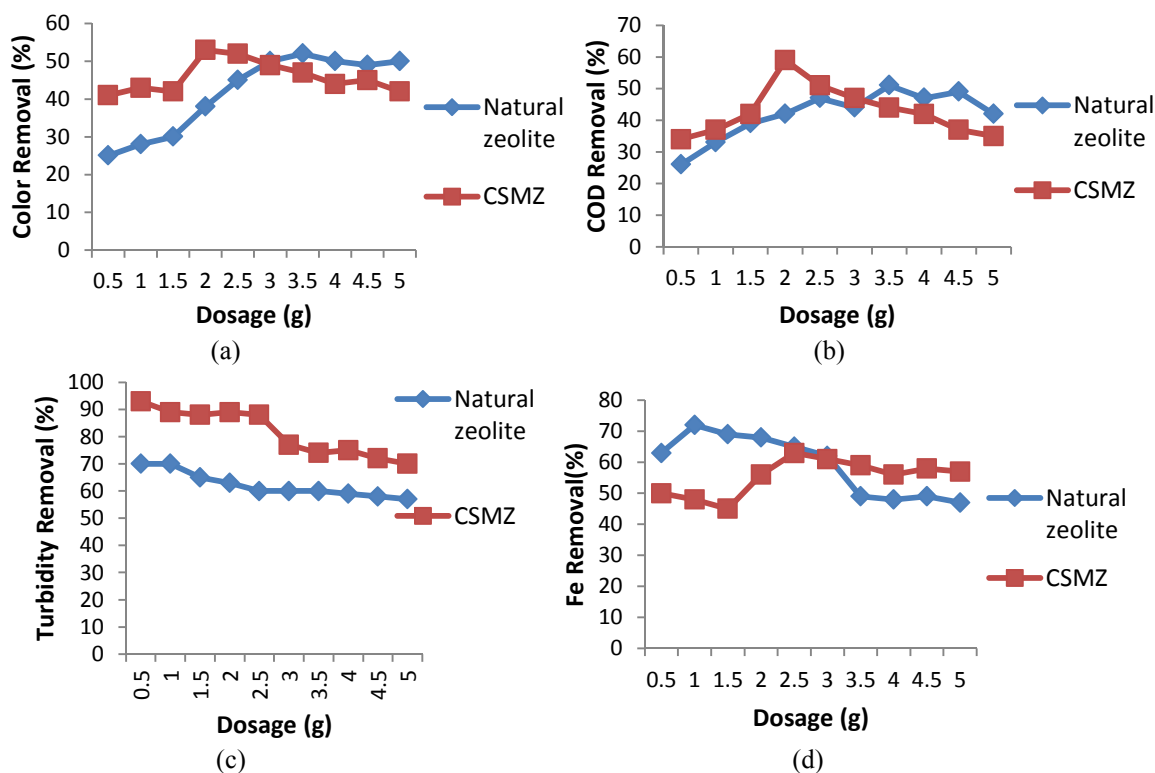
Figure 3. Percentage of color (a), COD (b), turbidity (c), and Fe (d) removal against pH for NZ, and CSMZ

Figure 3(a) displays the relationship between the amount of adsorbent mass (dosage) and adsorption efficiency for natural zeolite and CSMZ in terms of removing colour. The colour removal of peat water increased from about 25% to 52% with increasing adsorbent dosage of natural zeolite from 0.5 g to 3.5 g whereas for CSMZ, removal percentage increased from 41% to 53% with increasing adsorbent dosage from 0.5 g to 2.0 g. However, further increase in adsorbent dosage to 5.0 g only led to slight degradation of removal efficiency to 50% and 41% for natural zeolite and CSMZ respectively. This degradation with further increases in adsorbent dosage was due to the unsaturated adsorption active sites during the adsorption process since the adsorbates in the vessel were only shaken for 20 minutes (insufficient time). Besides, modification of zeolite by cationic surfactant had proven to have better colour removal as presented in the graph.

Percentage removal of COD against the adsorbent dosage is shown in Figure 3(b). It was observed that the highest percentage removal for both natural zeolite and CSMZ to remove COD were 51% and 59%, achieved at adsorbent dosage 3.5 g and 2.0 g respectively.

The variations in removal of turbidity of peat water at various system pH are shown in Figure 3(c). The removal rate of turbidity was highest at the adsorbent dosage of 0.5 g with 70% and 93% removal efficiency for respective natural zeolite and CSMZ. The removal rate showed a smooth downward trend with the increase in adsorbent dosage. Concurrently, the adsorption capacity gradually decreased with the increasing adsorbent dosage. The least efficient removal of turbidity was noted at dosage 5.0 g with percentage removal recorded for natural zeolite and CSMZ only 57% and 70% respectively.

Figure 3(d) demonstrates the percentage iron ion removal of natural zeolite and CSMZ with respect to their dosage. The result shows that there was a significant difference trend in iron ion adsorption efficiencies between natural zeolite and CSMZ. For natural zeolite, it was shown that the removal percentage of iron ion had increased until it reached 1.0g of dosage with 72% of removal efficiency. On the other hands, CSMZ was only able to remove about 63% of iron ion when its dosage was increased to 2.5 g. The lowest percentage removals were 47% and 57% recognized at the adsorbent dosage 5.0 g for respective natural zeolite and CSMZ.
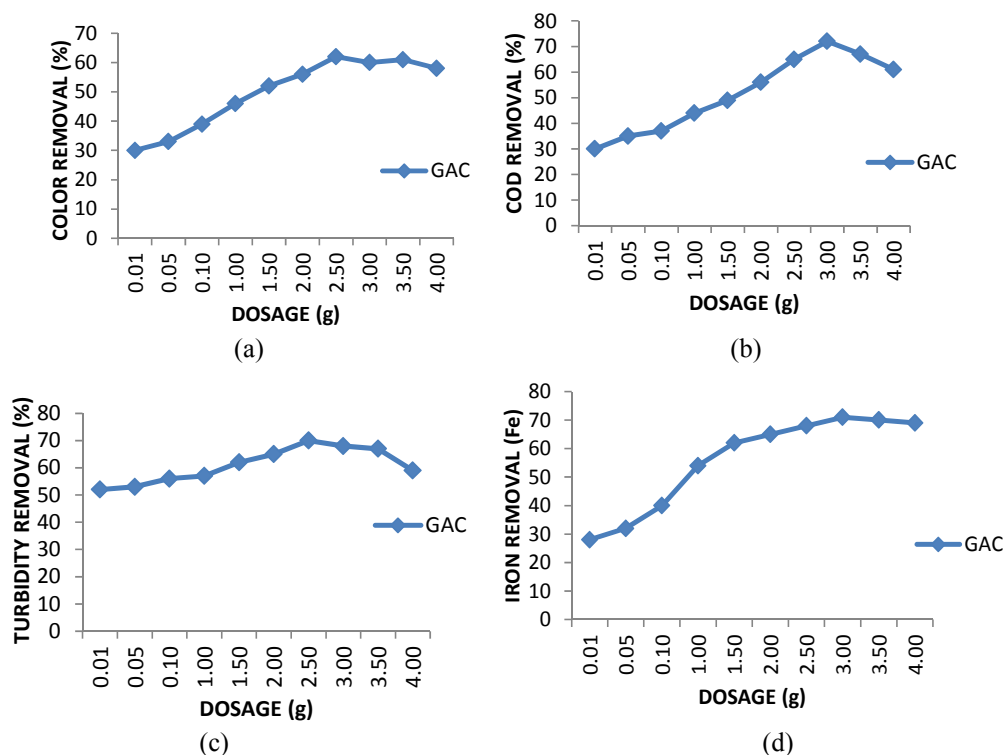
Figure 4. Percentage of color (a), COD (b), turbidity (c), and Fe (d) removal against dosage for GAC

The result illustrated in Figure 4(a) shows the maximum removal percentage of colour for GAC at 2.5 g dosage was 62%. Moderate increment in colour removal was identified along with the addition dosage of 2.5 g whilst abatement of removal efficiency began subsequently at adsorbent dosage of 3.0 g to 4.0 g.

The results from Figure 4(b) indicated that increasing the GAC dosage would increase the efficiency in removing COD respectively. The optimum dosage was recorded at 3.0 g with 72% of removal efficiency. Meanwhile, increasing the dosage above 3.0 g exhibited a slight decrease in removal efficiency with 67% to 61% for COD removal. A better result in removing COD was also shown by GAC compared to the natural zeolite and CSMZ.

The percentage of turbidity removed by GAC in different dosages is described in Figure 4(c). The highest removal was indicated at adsorbent dosage 2.5 g with removal efficiency of 70% while the minimum removal was 52% recorded at the adsorbent dosage 0.01 g. However, starting from adsorbent dosage of 3.0 to 4.0 g, removal efficiency began to decrease to 68%, 67%, and 69% respectively.

The result of percentage removal of iron ion by GAC in peat water is presented in Figure 4(d). It was found that the rate of removal was rapid in the initial dosage between 0.01 g to 3.0 g at which the removal efficiency increased from 28% to 71% accordingly. Subsequently, a few significant changes in the rate of removal were observed. Possibly, at the beginning, the solute molecules were absorbed by the exterior surface of adsorbent particles, so the adsorption rate was rapid. However, after the optimum dose was reached, the adsorption of the exterior surface becomes saturated and thereby the molecules will need to diffuse through the pores of the adsorbent into the interior surface of the particle (Ahmad & Hameed, 2009).

3.4 Batch Column Experiment

On the first running, the column was packed with natural zeolite (1st layer), limestone (2nd layer), and GAC (3rd layer) as shown in Figure 5(a). Removal efficiency for colour, COD, turbidity, and iron ion was recognized to be increased when the contact time was increased. At the time interval 1 hour to 6 hours, however, the increment was not so significant. The removal efficiency at 1 hour treatment was 39%, 21%, 54%, 36% while at 6 hours treatment was 77%, 65%, 73%, 60% recorded for respective colour, COD, turbidity, and iron ion. Poor removal efficiency at 1 hour treatment indicated that the required time to remove all parameters were insufficient. It is evident that if the adsorption process is allowed to run for 24 hours on the column, the removal efficiency shows notable removal. Percentage removals of colour, COD, turbidity, and iron ion at 24 hours were 83%, 72%, 76%, 65% respectively. Furthermore, the highest removal for respective colour, COD, turbidity, and iron ion were obtained at 48 hours treatment with 87%, 81%, 86%, and 79% of removal efficiency.
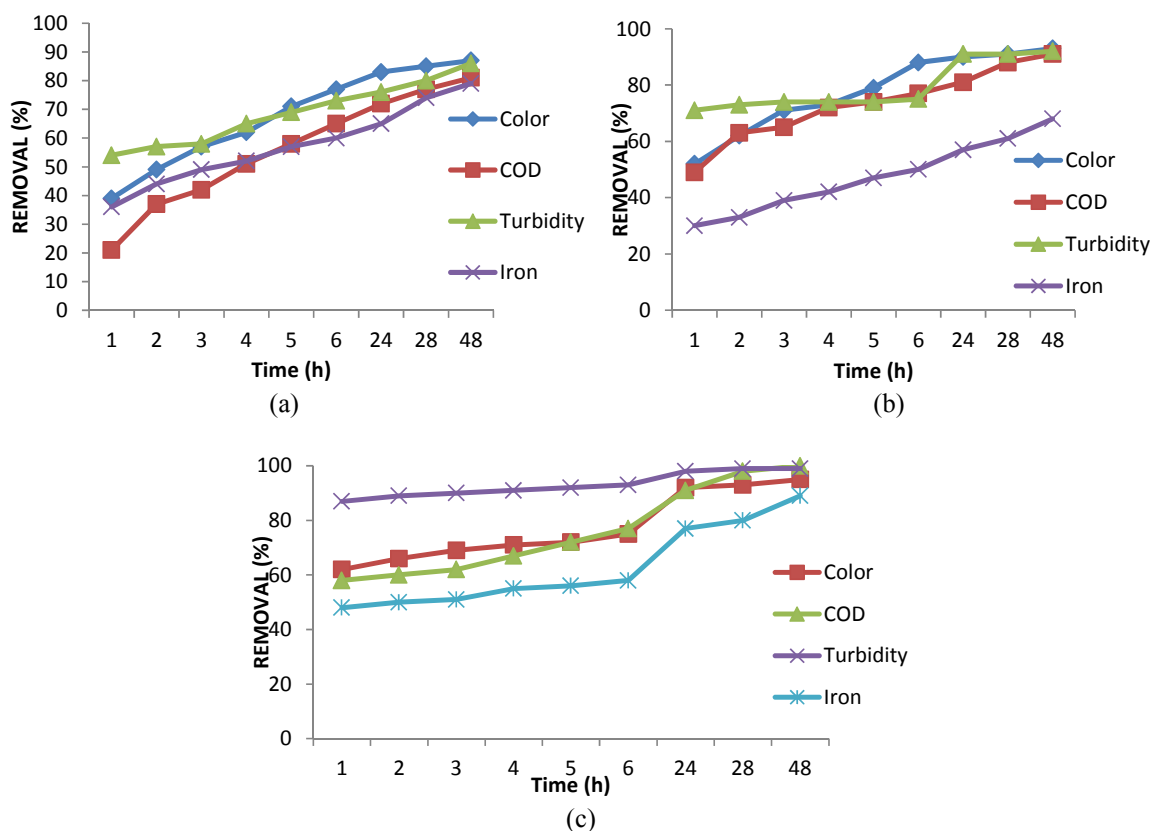
Figure 5. Percentage removal of color, COD, turbidity, and Fe for 1st run(a), 2nd run(b), and 3rd run (c) at flowrate 30 ml/min

On the second running, the column was packed with CSMZ (1st layer), limestone (2nd layer), and GAC (3rd layer) as presented in Figure 5(b). The removal percentages of colour, COD, turbidity, and iron ion were noticed after 1 hour to be 52%, 49%, 71%, and 30% respectively. The time of contact between adsorbate and adsorbent is proven to play an important role during the uptake of pollutants from peat water samples by adsorption process. In addition, the development of charge on the adsorbent surface was governed by contact time and hence the efficiency and feasibility of an adsorbent for its use in water pollution control can also be predicted by the time taken to attain its equilibrium (Sharma, 2003). Removal efficiency of 90% for colour, 81% for COD, 91% for turbidity, and 57% for iron ion were obtained at 24 hours of contact time.

On the third running, the column was packed with a difference sequence of CSMZ (1st layer), GAC (2nd layer), and limestone (3rd layer) demonstrated in Figure 5(c). It can be seen that the adsorption of these four parameters were slightly rapid at time interval 1 hour to 6 hours treatment. Further gradual increment with the prolongation of contact time form 24 hours to 48 hours has also occurred. Observation at 1 hour treatment recorded the removal efficiency of 62%, 58%, 87%, and 48% for respective colour, COD, turbidity, and iron ion. Whereby, 6 hours treatment had yielded higher removal percentage removal of 75%, 77%, 93%, and 58% respectively for colour, COD, turbidity, and iron ion. Further removal of colour, COD, turbidity, and iron ion was recorded when the treatment was run for 24 hours which exhibited 92%, 91%, 98%, 77% of removal efficiency respectively. Prolonged time to 48 hours indeed showed better removal of colour, COD, turbidity, iron ion with percentage removal of 95%, 100%, 99%, and 89% respectively. It can be seen that the arrangement of CSMZ, GAC, and limestone has the highest removal efficiency for all parameters at the flow rate influent of 30 ml/min.
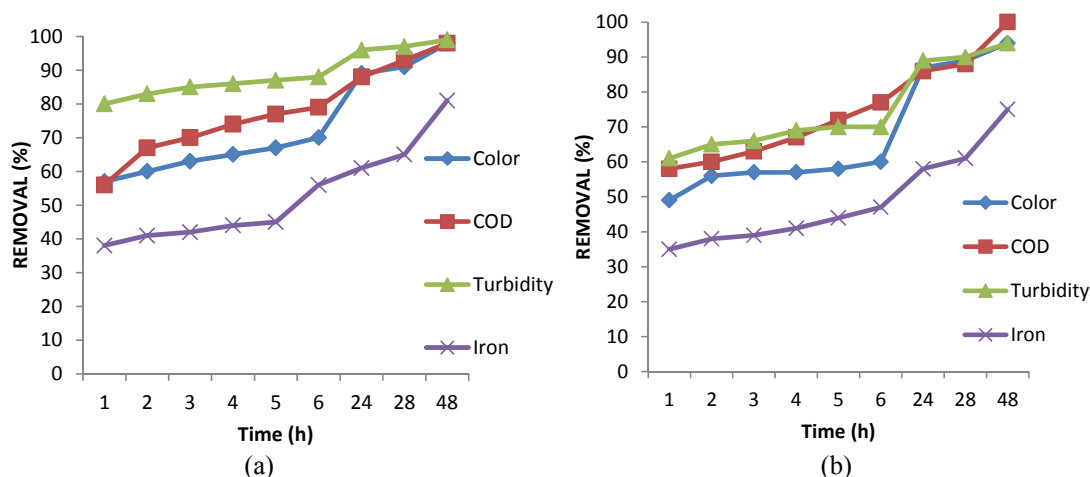
Figure 6. Percentage removal of color, COD, turbidity, and Fe against contact time for 2nd run(a) at flow rate 60 mL/min and at flowrate 90 mL/min (b)

The experimental adsorption behaviour was further seen for its adsorption capacity during 60 ml/min and 90 ml/min flow rate. In addition, the flow rate adjustment had also resulted in differences in surface loading rate in which the sample going through the surface area of adsorbent bed (horizontal surface area, A= 22.9 cm^2) for 30 ml/min equals to 1.31 cm/min while the flow rate of 60ml/min equals to 2.62 cm/min, and the flow rate of 90 ml/min equals to 3.93 cm/min. The percentage removal for both flow rate adjustments of CSMZ, GAC, and limestone arrangement were exhibited in Figure 6 (a) and Figure 6 (b). Based on these Figures, lower removal efficiencies were indicated at 1 hour time interval of 6 hours of contact time. The percentage removals for both 60 ml/min and 90 ml/min flow rate at 1 hour were 57%, 56%, 80%, 38% and 49%, 58%, 61%, 35% for colour, COD, turbidity, and iron ion respectively. Subsequently, when the contact time was at 6 hours, the removal percentage were 70%, 79%, 88%, 56%, and 60%, 77%, 70%, 47%. However, the maximum removal efficiency at 48 hours for both flow rates was not much different from the 30ml/min flow rate.

3.5 Adsorption Isotherm

In the present investigation, the experimental data were tested with respect to both Freundlich and Langmuir isotherms. Based on the linearized Freundlich isotherm models for natural zeolite, CSMZ, GAC in terms of adsorptive capacity to remove colour, COD, turbidity, and iron ion, the majority of them exhibited fits for all adsorbate with regression value (R^2) above 0.6, except for iron ion and turbidity for respective CSMZ, and GAC. On the other hand, the linearized Langmuir isotherm models for natural zeolite, CSMZ, GAC in terms of

adsorptive capacity to remove colour, COD, turbidity, and iron ion, had exhibited fits for all adsorbate with regression value (R^2) was at range of 0.242 to 0.912. The Langmuir isotherm model for all adsorption mechanisms were identified to have smaller R^2 values compared to the Freundlich isotherm model. Thereby, it can be concluded that the Freundlich isotherm model was more applicable in determining the adsorption mechanisms for this study.

3.6 Peat Water Quality Post Column Treatment

Peat water treatment in column with serial sequence of natural zeolite, CSMZ, and limestone had exhibited the highest removal with percentage removal at 48 hours at 95%, 100%, 99%, and 89% for colour, COD, turbidity, and iron ion respectively. Final readings at 48 hours treatment on pH, TDS, DO, conductivity, salinity, colour, turbidity, COD, and iron ion were 7.78, 74 mg/l, 4.03 mg/l, 137 uS/cm, 0.05 ppt, 12 TCU, 0.23 NTU, 0 mg/l, and 0.11 mg/l respectively (see Table 3). These findings, on the other hand, have indicated that peat water treatment had successfully produced water which satisfied the standard drinking water quality.

Table 3. The characteristics of results of peat water treatment from Beriah Peat Swamp Forest

Parameters	Unit	Average Value	Results after 48 hr	Standard Limit[*)]
pH	-	4.67 - 4.98	7.78	6.5 - 9.0
Temperature	°C	27.8	29	-
TDS	mg/L	20.6	74	1000
DO	mg/L	3.4	4.03	7
Conductivity	uS/cm	34.5	137	1000
Salinity	ppt	0.02	0.05	0.5
Color	TCU	224.7	12	15
Turbidity	NTU	20.8	0.23	5
COD	mg/L	33.3	0	10
Iron, (Fe)	mg/L	1.24	0.11	0.3
NH_3-N	mg/L	0.51	NA	1.5

Note: 1. [*)]Malaysian standard for drinking water quality;

2. NA = Not analyzed.

4. Conclusions

From the results presented in this paper, the following conclusions can be drawn:

1)   The optimum removal of colour, COD, and turbidity for all adsorbents were observed to occur during acidic conditions at pH range 2 - 4 whereas for iron ion, the maximum removal was noted at pH range 6 - 8.

2)   At pH 2, CSMZ yielded the highest removal for colour and turbidity with removal efficiency of 90% and 98% respectively. Meanwhile, GAC has the highest percentage removal of COD at pH 4 with removal efficiency obtained about 61% while at pH 6, GAC exhibited the best removal of iron ion with percentage removal around 80%.

3)   CSMZ revealed stronger adsorptive capacity for colour, COD, and turbidity compared to natural zeolite.

4)   The optimal removal was achieved for the serial sequence of CSMZ (1st layer), GAC (2nd layer), and Limestone (3rd layer) with the adsorbent media at 30 ml/min of flow rate.

5)   Freundlich isotherm was more reliable to describe the adsorption mechanisms of colour, COD, turbidity, and iron ion for natural zeolite, CSMZ, and GAC.

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