PREPARATION OF ACTIVATED CARBON FROM PEAT

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Peat with an approximate 60% carbon content collected in the suburbs of Palangka Raya, Indonesia, was carbonized, followed by activation with steam in an electric furnace. The resultant activated carbon (AC) had ca. 900 m^2/g of BET surface area and 1000 mg/g of iodine adsorption. This performance implies that this AC can be used as an adsorbent for environmental purification. We had a carbonizing furnace manufactured in Palangka Raya, which did not require electric power. Some AC having 350 mg/g of iodine adsorption was obtained by using this furnace. Although the adsorption ability was much lower than that of commercially available AC, the AC achieved significant decoloration and decrease in chemical oxygen demand of polluted river water. Thus, this article demonstrated the potential of tropical peat soil as a source of AC.

Keywords: Activated carbon; COD; Kalimantan; Peat; Peatland; Portable furnace; Purification of river water

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INTRODUCTION

Biomass has received much attention as an alternative organic resource. This is because fossil resources are facing a shortage and their utilization causes environmental problems. However, it is necessary to use biomass that does not compete with food production, since the price of food feedstocks, such as corn, has been remarkably increased as a result of increased demand due to bioethanol production as a fossil fuel substitution. Peat is a partially carbonized phytomass, and it is considered to be suitable for the requirements of some biomass applications. In fact, it has been used as a smoky flavor source for whisky manufacturing for several centuries, and as a raw material for production of carbonaceous materials (Drozhalina 1981; Sipila et al. 1984; Polania-L. et al. 1993; Veksha et al. 2008). Taking the partially carbonized character of peat into consideration, it seems a more suitable raw material when producing carbonaceous materials in terms of the energy consumption and cost.

In the highly populated area of Southeast Asia, the production of the domestic purified water, drinking water in particular, is a very important subject from the view-points not only of daily life but also public sanitation. It is preferable that the water should be produced in the regions of consumption in order to reduce transportation energy and cost. Therefore, it is reasonable that purification agents for water, among which ACs are mainly used, should also be produced in the same regions.

In Indonesia, huge amounts of AC having excellent performance are being produced from coconut shell, but this is a valuable export material. Therefore, the AC for daily use had better be obtained from other resources. In this study, we attempted to produce AC from tropical peat soil obtained in Kalimantan island, Indonesia, by a system similar to that being used in the case of coconuts shell. This research would result in production of not only a domestic purification agent but also export material.

On the island, especially in central Kalimantan province, a huge area of dried peatlands was generated for a few decades by artificial channel migration and climate change. The burning of peatlands in the dry season upon natural ignition or spot fires from artificial field burning is causing an environmental problem, haze. Accordingly, the maintenance of the peatlands, such as irrigation, is an urgent problem. Thus, the peat exhausted from the maintenance and surface of peatland after burning seems to be a promising resource, although the use of large quantities of peat also brings about environmental problems. There has been a report on the production of activated carbon from peat (Mudjijati et al. 2000). However, that AC was produced by chemical activation with $ZnCl_2$ and H_3PO_4. Those reagents are hazardous, and the system requires several processes and special equipments for the preparation. Therefore, the method is not suitable for the production of AC in a domestic manufacture.

In the present article, we examined the performance of ACs prepared from peat and coconuts shell by means of steam activation, which required only water without special equipments, in an electric furnace. A fundamental analysis of the peat was carried out. In addition, we had a portable furnace manufactured, which did not use electric power. The performance of AC prepared by the furnace was also evaluated.

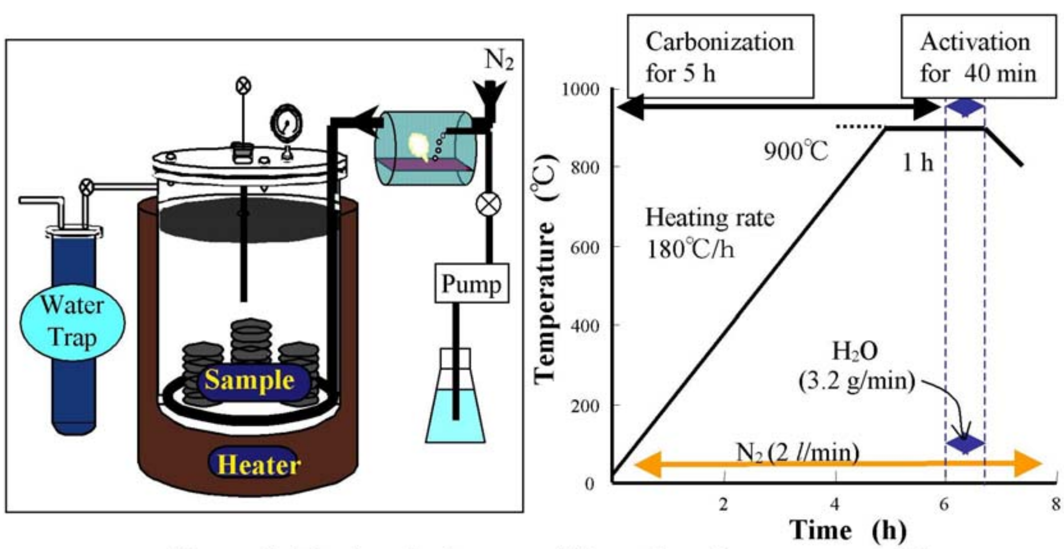


Figure 1. Electronic furnace (A) and heating process (B) for production of activated carbon.

EXPERIMENTAL

Peat and Preparation of AC

The peat was collected every 20 cm from the land surface to 3.6-m depth in the Kapuas border region (South latitude, 2^o20'39.5"; East longitude, 114^o02'17.1"), Palangka Raya. After complete drying at 105 ^oC, the peat was subjected to elemental analysis. Coconut shell was kindly supplied by Dr. Maman Turijamon in Forestry Research and Development Agency, Bogor, Indonesia. The shell was crushed and cut into about 3-cm squares.

The peat collected from 0 to 1, 1 to 2, and 2 to 3-m depth was combined and dried. The peat and coconut shell pieces were placed in steal meshed baskets, and the baskets were heated in an electric furnace (Fig. 1) (Uraki et al. 2004) up to 900 ^oC at a heating rate of 180 ^oC/h, and that temperature was maintained for 1h. Then, steam that was generated by dropping water onto the hotplate at 150 ^oC was introduced into the furnace at 900 ^oC, together with a stream of nitrogen at a flow rate of 2 l/min for 40min.

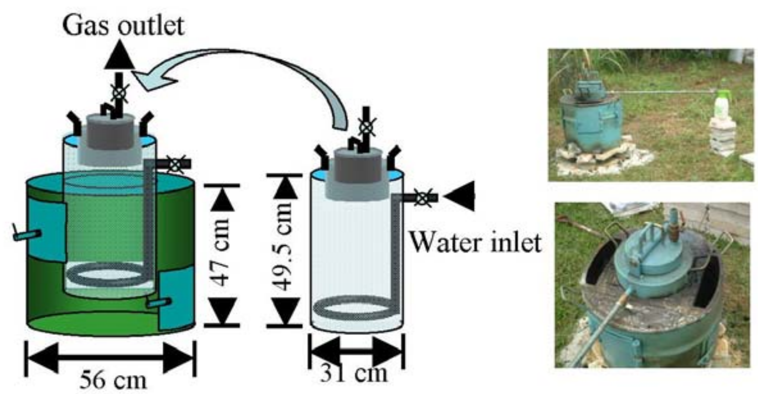


Figure 2. Portable furnace manufactured in Palangka Raya for production of activated carbon.

A portable furnace for preparing AC was manufactured from waste gasoline drum and iron pipe that were easily obtained in a factory of Palangkaraya, Indonesia, as shown in Fig. 2. The furnace is comprised of two parts; an outer side of the drum is a heating part, and the inner part is a furnace. Wood charcoal was used as fuel, as no electric power was used. Water for activation was supplied by a modified spray pump for gardening. The peat and coconuts shell pieces were carbonized, followed by activation with steam. The AC preparation from peat and coconuts shells, as well as the evaluation of adsorption performance of the resulting AC, were carried out three times in Palangka Raya.

Evaluation of Adsorption by AC

BET specific surface area and pore size distribution of AC were measured on a SORPTOMATIC 1990, Fisons Instruments, after drying samples at 200 ^oC overnight. The pore size distribution was calculated by the Dollimore Heal method (Dollimore and Heal 1964). Iodine adsorption was measured in accordance with Japan Industrial Standard (JIS) K-1474.

Evaluation of Pollution of River Water

Chemical oxygen demand (COD_{OH}) of river water from Kahayan river and canal by CIMTROP, Palangkaraya, was measured by titration with sodium thiosulfate aqueous solution for permanganate consumption according to the alkaline COD method in JIS K-0102. Total coliforms in the river water were measured after 2-days culture at room temperature by using an easy detection kit (Petan Check) for *E. coli* produced by Eiken Chemicals, Tokyo, Japan.

RESULTS AND DISCUSSION

Peat

Table 1 shows the elemental analysis of peat collected in Kapuas border, Central Kalimantan province. The carbon contents were almost identical (ca 60%), not dependent on the depth of the obtained peat. The contents were higher than that of wood, evidencing that peat was a partially carbonized biomass. In addition, the peat seems to be a promising raw material for carbonaceous materials, since there was no ash.

Table 1. Elemental analysis of peat at Kapuas boarder

Depth (cm)	C (%)	H (%)	N (%)	Ash (%)
0 - 20	61.01	4.69	1.03	N.D.
60 - 80	60.95	4.16	0.66	N.D.
120 - 140	61.51	4.25	0.71	N.D.
180 - 200	60.22	4.53	0.73	N.D.
240 - 260	60.90	3.95	0.61	N.D.
300 - 320	60.42	4.47	0.89	N.D.
340 - 360	61.13	4.40	0.85	N.D.
Fir[a)]	50.36	5.92	0.05	0.28

[a)] These values are cited from Migita (1968)

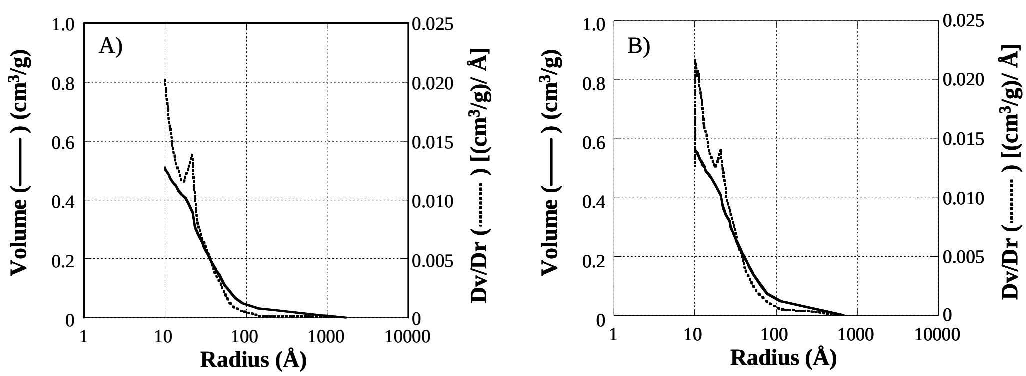
Preparation of AC in an Electric Furnace

The peat from Central Kalimantan was carbonized and successively activated with steam without cooling to take out charcoal in an electric furnace, although AC was, in general, prepared by two-step heating for carbonization to produce charcoal, followed by activation after taking out the charcoal (Mouri 2005). Thus, the carbonization and steam-activation in this system were carried out by heating just once, thus simplifying the production process and reducing the cost. The fundamental properties for evaluation of AC performance are listed in Table 2. The BET surface area of all ACs were approximately 900 m^2/g (S.T.P.), and iodine adsorption capacities were in the range of 970 to1100 mg/g with yields of 20 to 24% based on the dry peat. These adsorption performances were comparable or slightly inferior in comparison to those of commercially available AC. There was, in general, a negative correlation between AC yield and adsorption performance; the lower the yield, the more excellent the performance. Since a typical yield of commercial AC is less than 10%, the peat AC showed considerably excellent adsorption ability, in spite of its high yield. Thus, the peat soil in Central Kalimantan proved to be a promising source for AC.

Table 2. Adsorption properties of AC from peat prepared in an electric furnace.

Depth (cm)	Yield (%)	I_2 capacity (mg/g)	BET surface area (S.T.P. m²/g)	Pore specific volume (cm³/g)
0 - 100	24.4	974	862	0.70
100 – 200	21.3	1150	890	0.82
200 – 300	20.3	1090	891	1.03

Figure 3 shows the pore size distribution, cumulative, and derivative profiles, of the peat ACs. The cumulative area of AC prepared from peat collected in depth range of 2-3 m at a radius of 10 nm (0.2 cm^3/g) was much larger than other ACs at depths of 0-1 m and 1-2 m (ca 0.06 cm^3/g). Such large pores contributed to a larger pore specific volume of the AC within the depth range of 2-3 m. In addition, the development of micropores was obviously observed in Fig. 3. Therefore, these ACs are expected to adsorb gaseous materials.



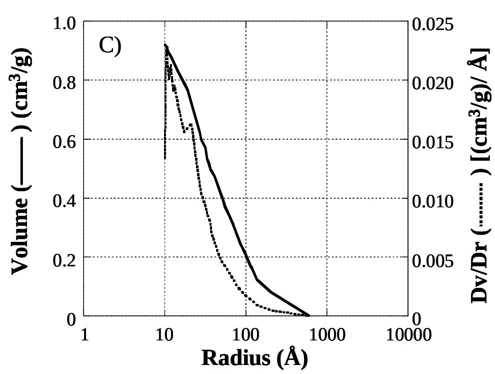


Fig.3 Pore size distributions of AC from peat. (——), cumulative plot; (············), derivative plot. The distribution was calculated by the Dollimore Heal Method. Peat was collected in the depth of 0-1 m (A), 1-2 m (B), and 2-3 m (C) at Kapuas border.

Preparation of AC in a Portable Furnace

A portable furnace for preparing AC was manufactured with use of common materials that were easily obtained in Palangka Raya, Indonesia. The furnace was designed so that it would be easily manufactured in South-east Asia area, would be portable, and would not require electric power. This AC preparation using the furnace was carried out only three times, because the preparation and evaluation of AC adsorption ability were conducted for one week during our stay in Palangka Raya.

Using this apparatus, the temperature of the inner part of the device was easily elevated up to 200 ^oC within 30 min after the start of heating, and it reached 450^{o}C for 1 h, but the highest temperature of inner part was approximately 500 ^{o}C. The time course of temperature in the inner part and the timing of steam-activation are shown in Fig. 4.

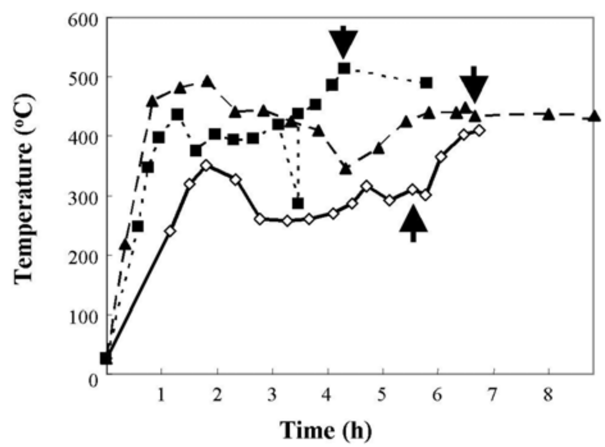


Figure 4. Temperature of inside of portable furnace during the production of activated carbon on 22nd (◇), 23rd (■) and 24th (▲) of September, 2005 . Arrows indicate the beginning time of water introduction into the furnace.

Table 3. Yield and Iodine adsorption of activated carbons prepared from peat and coconuts shell

Entry	Source	Date	Yield (%)	I_2-adsorption (mg/g)
1	Peat	22. Sep	39.9	154
2	Coconuts shell	23. Sep	22.4	315
3	Peat	24. Sep	27.5	350
4	Coconuts shell	24. Sep	25.1	328
5	Charcoal			114

The adsorption abilities of the resultant carbonaceous materials are listed in Table 3. The iodine adsorption capacities of the materials were as low as 350 mg/g. In general, the value of iodine adsorption was very similar to that of the specific BET surface area (Moon et al. 2000; Phussadee and Prasert 2008). These carbonized materials might have much lower surface area as compared with commercial AC, and could not be, therefore, referred to as AC. Table 3 clearly indicated that the peat was carbonized and activated to the same extent as coconut shell. However, it was found that the activated peat achieved comparable and/or superior adsorption performance to the activated coconuts shells prepared under the same conditions. The results demonstrated potential for river water purification.

Table 4. Effect of activated carbon treatment on CODOH of creek water by CIMTROP

Charcoal				
Weight of sample (g)	0	2.0	5.1	10.0
COD_{OH} (mgO/L)	8.75	8.45	7.71	7.65
Coconuts shell activated carbon (Entry 4 in Table 3)				
Weight of sample (g)	0	2.0	5.0	10.0
COD_{OH} (mgO/L)	8.75	7.76	7.84	7.60
Peat activated carbon (Entry 5 in Table 3)				
Weight of sample (g)	0	2.0	5.0	10.0
COD_{OH} (mgO/L)	8.75	7.89	6.53	5.16
pH	6.8	7.7	8.2	8.6
Fe (mg/L)	0.5-1	0.1-0.3	<0.05	<0.05

COD_{OH} of creek water is 8.75 mgO/L.

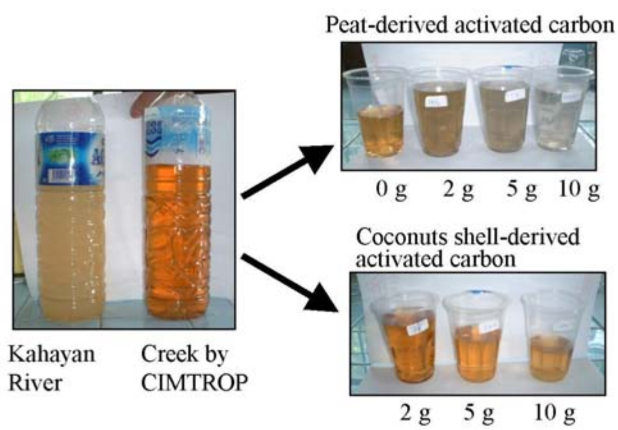


Fig. 5. Decolorization of creek water with activated carbons

Prior to an experiment for river water purification, the chemical oxygen demand was measured for water of two rivers, Kahayan river and a canal flowing through the grounds of the University of Palangka Raya. The COD of the Kahayan river water (3.86 mgO/L) was smaller than that of the canal water (8.75 mgO/L). From the data, it is understandable that the river water was sometimes drunk by the residents under urgent situations. In this experiment, the canal water was used because it was considerably colored and polluted. Figure 5 and Table 4 show decoloration of river water and COD reduction as a measure of water purification, by the addition of activated peat and coconut shell products to river water in Palangka Raya. The brown color of the water was decolorized with increasing added amounts of the activated peat. Although gray color still remained when 10-g of the peat AC was charged, the color was caused by the fine AC powder that was passed through paper filter. Therefore, decoloration with peat AC was almost performed. On the other hand, the degree of decolorization upon the activated coconuts shell prepared under the same conditions as activated peat production was weaker than that upon the activated peat. As shown in Table 4, the COD was reduced by 41% by using 10g of the activated peat, and the Fe content was also decreased. This implied that this activated material had significant ion-exchange ability. Concurrently pH was increased by the activated peat. This would be attributed to ash in the material. Actually, the activated carbon contained approximately 4% of ash, although any ash in the raw material, peat, was not detected. By the visible inspection of colony numbers of *E. coli* after 2-days culture at room temperature using an *E. coli* detection kit, the number of colonies was significantly decreased with increasing charge of activated peat to the river water. This change in activity might be brought about by the high pH. Therefore, the activated peat acted not only as an adsorbent for organic and inorganic materials but also as an anti-bacterial agent.

CONCLUSIONS

1. Peat, which is a considerably carbonized biomass, could be converted into activated carbon (AC) with satisfactory adsorption performance, comparable to that of coconuts shells, by carbonization and successive activation at high temperature (900^{o}C) in an electric furnace.
2. The AC from peat was attempted by manufacturing a furnace for AC production. The unit was designed for portability, for having no requirement of electric power, and it was manufactured in Palangka Raya, Indonesia. Unfortunately, the intended AC could not be obtained, because a sufficiently high temperature inside the furnace was not attained. This was attributed to a bad design of the furnace. However, the peat was converted into activated materials as effectively as coconuts shells.
3. The peat-activated materials revealed more excellent adsorption performance for decoloration and COD reduction of polluted river water. In addition, the peat-derived materials brought about pH increase, leading to depression of *E. coli*. Thus, peat is a promising raw material for AC production, and it is easily convertable into AC as well as coconuts shell by the same procedures.

It follows that in South-East Asia, peat and coconuts shell can be utilized as biomass resources for AC production for export and domestic use of AC.

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