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ARTICLE

Investigation on characterization of different types of coals and preparation of coal-derived activated carbon

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Abstract: Activated carbon consumption is continuously increasing because of their application in such important areas as waste and drinkable water treatment, atmospheric pollution control, hazardous gas separation, cleaning of solvents, etc. Every year, Mongolia imports 700-800 tons of activated carbons for 700-900 USD per ton. We have selected 3 different types of coal, including a high ranking bituminous coal from Tavantolgoi deposit, stone sub-bituminous coal from Shariin Gol mine and brown lignite coal from Baganuur deposit and they were each enriched with heavy liquid, such as zinkum chlorade solution and processed by semicoking (carbonization) method to produce the main raw material for coal-derived active carbon. Using these carbonized coals, we have obtained coal-derived activeted carbon by activation with preheated water steam for 120 minutes. The most important technical properties of initial coal samples and activated carbons and their microporous properties, such as iodine number in percentage, methylene blue adsorption mg/g and surface area (BET)-m^2/g were determined and characterized. The determined iodine number of activated carbon of purified and carbonized coals increased by 5-17 times and methylene blue adsorptions also increased from 4 to 10 times as compared to pyrolysis hard residue of initial coal samples without purification and activation. Basing on this, we are proposing a thecnological scheme for the production of coal-derived activated carbon.

Keywords: *High rank coal, bituminous coal, stone sub-bituminous coal, brown coal, activated carbon, surface area;*

INTRODUCTION

Mongolia has a total resource of 173 billion tons of different kinds of coals. They include high-ranking bituminous, stone sub-bituminous coal and brown coals of lignite type, which are distributed all across the territory of Mongolia. Mongolia is one of the 10 coal-rich countries in the world and already has 28 billion tons of confirmed resources [1-3] of coal. Also, there are huge resources of other carbon containing (carbonaceous) organic wastes of plant and animal origin, which are not being used because of their pollution factors.

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In Mongolia, there are several rich deposits of high rank coals, such as the Tavantolgoi, Nariinsukhait and Saikhan ovoo deposits and huge resource of low rank coals, such as stone sub-bituminous and brown coal in the central and eastern parts of the country. We have chosen three different types of coal, including a high rank bituminous coal of Tavantolgoi deposit [4,6], stone sub-bituminous coal of Shariin gol [5] and brown lignite coal of Baganuur [6,7] deposit for investigation through thermal processing and preparation of coal-based activated carbons with high developed porosity structure and adsorbing property [8-11].

We have likewise worked on thermal processing and preparation of activated carbons from carbon containing (carbonaceous) organic wastes of plant and animal origin, for example, plant-origin wastes (sawdust) of the timber industry, coconut shell [12-13] and animal-origin wastes, such as casein [14-17] and bone [18-19] with good porosity structure and adsorbing properties.

Activated carbon consumption is continuously growing because they are used in such important areas as waste and potable water treatments, atmospheric pollution control, poisonous gas separation, solvent recovery etc. Almost any carbonaceous material can be converted into activated carbon, because of it's availability and low price, a great portion of activated carbon production is derived from natural coal. Activated carbons are not produced in Mongolia and hence the country imports 700-800 tons of activated carbons every year at a cost of 700 to 900 USD per every ton.

For this reoson we have decided to study coal-based and carbonaceous organic waste-based activated carbons.

MATERIALS AND METHODS

Table 1 shows the location, the type, the resource and other information of the investigated three types of coal samples from the Tavantolgoi, Baganuur and Shariin Gol mines.

Table 1. Some information about investigated coal deposits

№	Coal deposit	Location	Coal type and reserves	Year of discovery
1	Tavantolgoi	Tsogttsetsi *soum* of Southgobi *aimag*,14 km south from Tsogttsetsi *soum* and 600 km in south gobi from Ulaanbaatar	High rank bituminous and coking coal, geological reserves 6.4 billion tons.	1966
2	Baganuur	Bayandelger *soum,* Central *aimag*, 110 km south east of Ulaanbaatar	Lignite brown coal, geological reserves 713.1 million tons	1978
3	Shariin Gol	Darkhan city in Darkhan Uul *aimag*, 80 km from Darkhan.	Stone coal, geological reserves 69.9 million tons	1965

Analytical samples of coals from these three deposits were prepared according to Mongolian National Standards (MNS) and the key technical characteristics, including moisture (MNS 656-79), ash (MNS 652-79), volatile matter (MNS 654-79), caloric value (MNS 669-87), and sulfur content (MNS 895-79) have been determined.

Activated carbon samples from coals were prepared by using the following procedures:

1. Purification of initial coal samples in heavy liquid in order to decrease the content of ash;
2. Carbonization of purified coal by using the pyrolysis method, and,

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3. Activation of carbonized hard residues after carbonization by using preheated water steam

Purification of initial coal samples in heavy liquid of $ZnCl_2$ water solution

First of all, the coal samples were milled to a size of 1.0-1.5 mm and then sieved, Heavy liquid of water solution of $ZnCl_2$ with different densities-g/cm^3 (1300; 1400, 1500, 1600, 1700, 1800, 1900, 2000) were used for purifying the sieved coal samples. We were able to determine that the ash content decreased by more than 2 times with the use of water solution of $ZnCl_2$ with a density of 1300 g/cm^3. For this purpose, we used a tall glass cylinder filled in with water solution of $ZnCl_2$ with a density pf 1300 g/cm^3. The coal sample was put in the $ZnCl_2$ solution in the glass cylinder mixed well for 5 minutes and left for 24 hours until the formation of the upper and bottom fractions. The upper and bottom fractions were filtered separately in a filtering paper to determine their yield. as shown in Figure 1.

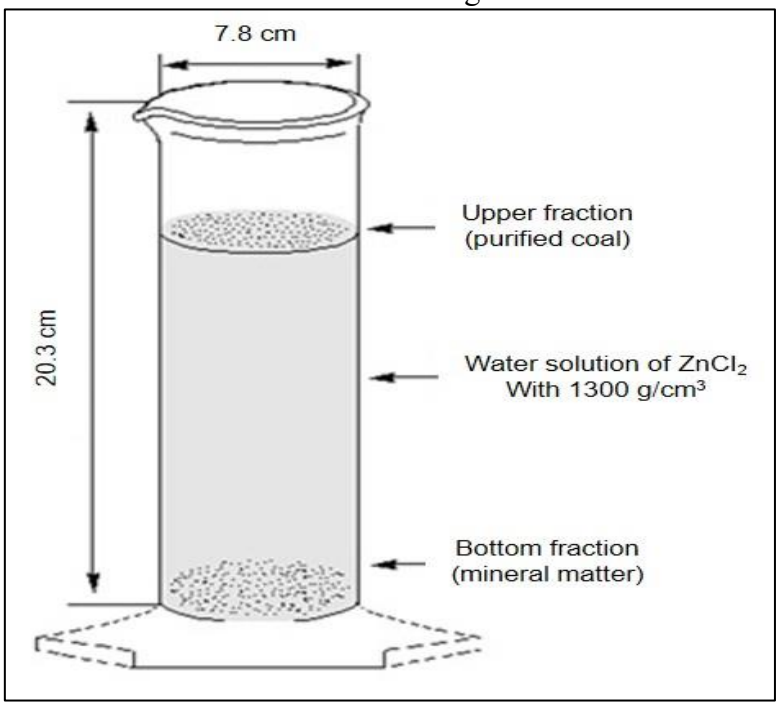

Figure 1. A schematic system of purifying initial coal samples in heavy liquid

Carbonization of purified coal by pyrolysis

The pyrolysis of coal samples were performed in a vertical cylindrical stainless steel retort with a capacity of 1000g. The retort was placed in an electric furnace (model SNOL) switched to a maximum temperature of 950°C. A chrome-alumel thermocouple was immersed in the *coal bed* to measure the actual temperature and an equipment for temperature control (potentiometer) was also used. The retort was connected with an air-cooled iron tube and water-cooled laboratory glass condenser and a vessel for collecting the condensate of liquid product (pitch and pyrolysis water). The non-condensable gases, after water-cooled condenser, were let through a thin glass tube. The experiment was carried out at a temperature of 700°C and the heating rate was 20°Cmin^{-1}. The yield of products, including solid residue (coal char), tar and pyrolysis water, was determined by weighing, and the yield of gases by their difference.

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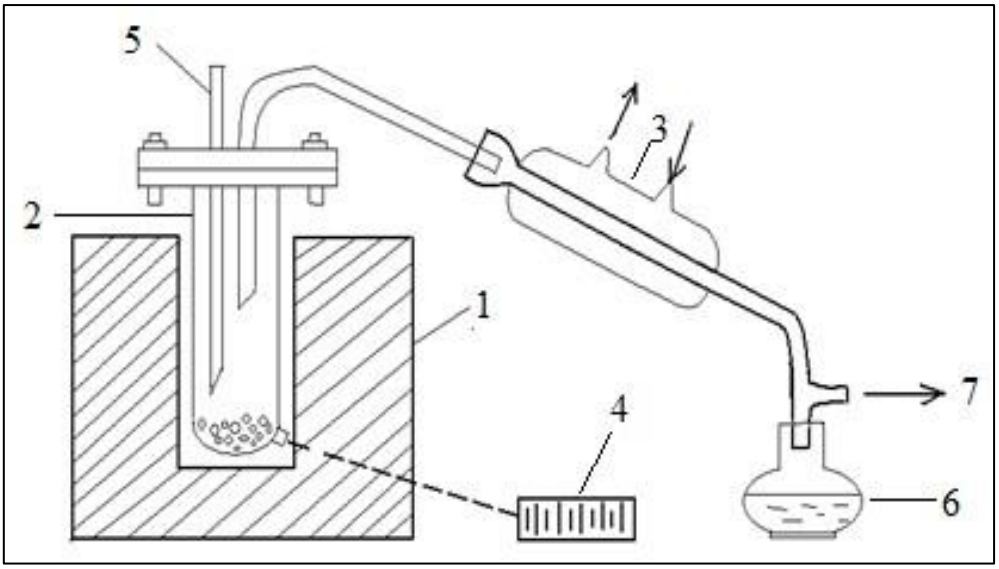

Figure 2. A schematic drawing of the equipment for the pyrolysis (carbonization) of coal
1 - Electric furnace (model SNOL Russian); 2 - Retort; 3 - Laboratory glass condenser (cooler); 4 - Millivoltmeter; 5 - Thermometer; 6 - Vessel for tar; 7 - Exit for uncondensed gas.

Activation of carbonized coal samples

The carbonized purified coal samples (10-15g.) were replaced in quartz tube and flowed with nitrogen to remove the oxygen and the sample were heated up to 800°C and processed (activated) with heated water steam for 120 minutes (Fig.3).

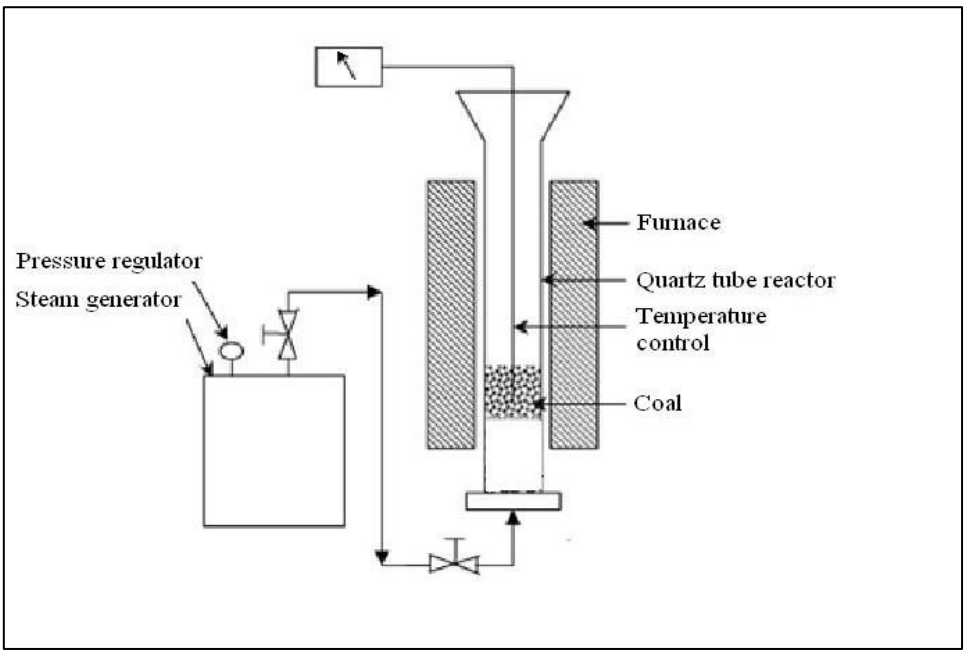

Figure3. A schematic drawing of the equipment for the activation of carbonized coal

Characterization of activated carbon samples

- Determination of Iodine number, in percentage

The iodine number, percentage of the activated carbon samples was determined by a standard method – GOST 6217-74.

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- *Determination of Methylene blue adsorption, mg/g.*

The methylene blue adsorption, mg/g of the activated carbon samples was determined by a standard method - GOST 4453-74.

RESULTS AND DISCUSSION

The results of technical analysis of the three initial coal samples from Tavantolgoi, Baganuur and Shariin Gol deposits are given in Table 2.

Table 2. Technical analysis results of coal samples from Mongolia

№	Coal deposit	Moisture, W^a %	Ash, A^d %	Volatile matter, V^{daf} %	Sulfur, S^d_t %
1	Tavantolgoi	0.95	10.70	28.00	0.90
2	Baganuur	10.18	10.60	44.00	0.51
3	Shariin Gol	7.83	7.40	40.90	0.60

The technical characteristics in Table 2 show that the content of ash is comparatively lower in all three coal samples. The content of sulfur is less than one per cent in all coal samples, which is good from an environmental point of view. The content of volatile matter is lowest in the Tavantolgoi coal and highest in Baganuur coal and also higher in the Shariin Gol coal. The content of volatile matter in all three coal samples show that the Tavantolgoi coal is of a high quality, the Baganuur coal is low rank brown coal and the Shariin Gol coal is an anthracite. Hence, it follows that the Tavantolgoi coal belongs to a sub-bituminous coking coal of KJ mark, the Baganuur coal belongs to an oxidized B2 mark coal of lignite type and the Shariin Gol coal belongs to a sub-bituminous anthracite coal.

The results of organic elemental analysis of the three initial coal samples from Tavantolgoi, Shariin Gol and Baganuur mines are shown in Table 3.

Table 3. The results of organic elemental analysis of coal samples

№	Coal deposit	C(%)	O(%)	S(%)	N(%)	H(%)	Ash (%)
1	Tavantolgoi	76.40	0.60	0.50	2.30	4.50	11.00
2	Baganuur	58.40	19.80	0.30	0.70	4.70	8.00
3	Shariin Gol	63.20	13.90	0.20	1.40	5.50	8.60

The content of C is highest and O is lowest in Tavantolgoi coal, which are characteristics of a high rank coal. C content is lower and O content is higher in Shariin Gol and Baganuur coals becuace of their low rank.

For the characterization of the three types of coal, we applied the FT-IR analysis of each coal sample and the results are shown in Fig.4.

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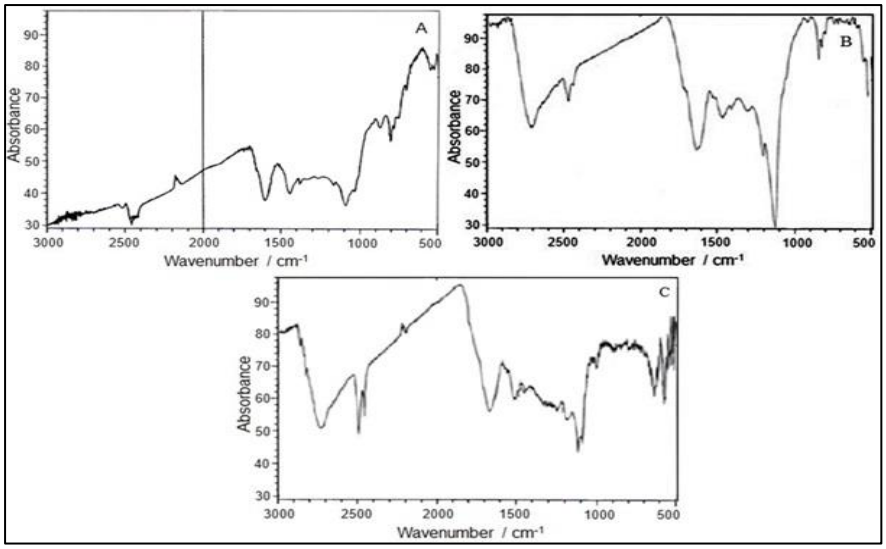

Figure 4. FT-IR spectrum of initial coal samples: Tavantolgoi coal (A), Baganuur coal (B) and Shariin Gol coal (C).

The following absorption frequency regions can be recognized in the IR spectra of initial coal samples of three deposits: 700-900 cm^{-1} for C_{ar}-H; 1000-1300 cm^{-1} for vibration of bonds in various oxygen-containing groups; 1350-1470 cm^{-1} for vibrations of –CH, $-CH_2$ and $–CH_3$ groups; 1500-1630cm^{-1} for skeletal vibrations of aromatic rings, >C=O bonds in ketones, aldehydes and quinines; 2800-2950 cm^{-1} for stretching vibrations of –CH, $-CH_2$,, $-CH_3$ groups in saturated aliphatic structures; and 3030-3350 cm^{-1} for stretching associated vibrations of –OH groups in aromatic rings and aliphatic structures. Coal from Tavantolgoi deposit is a high rank coal with more polymerized organic matter with lower reactivity. Therefore, the IR spectra of this coal is very week, not well defined and has continuous absorption bands.

For the investigation of the mineral composition of coal samples, we obtained ashes after continously and completely burning of each coal sample in furnace at at a temperature of 950°C. The IR spectra of coal ash samples from these deposit are presented in Fig. 5 and elemental and mineral oxide compositions determined by X-Ray Fluorescence method are given in Table 4.

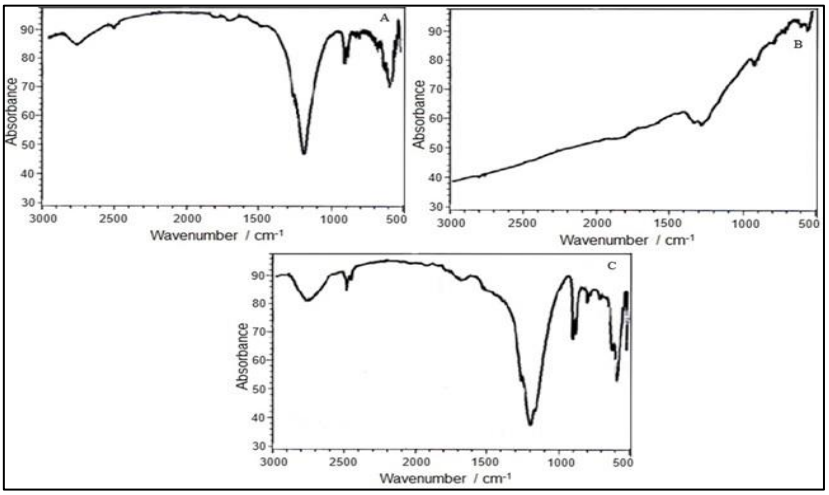

Figure 5. FT-IR spectrum of ash of initial coal samples: Tavantolgoi (A), Baganuur (B) and Shariin Gol (C) deposits.

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First of all, it can be noted that the most intensive and wide adsorption band in each IR spectra of coal ash samples from the three coal deposits (Fig. 5), which are as follows: 1060 cm^{-1} for Si-O- bonds in silicates (Saikhan Ovoo), 1091 cm^{-1} for Si-O- bonds in silicates (Tavantolgoi), and 1410 cm^{-1} for Ca-O- bonds in carbonites (Nariin Sukhait). Some other picks with lower intensity were observed, including in 3400 cm^{-1} for –OH groups in different minerals, 1000 cm^{-1} for Al-O- , 900-1000 cm^{-1} for Si-O- , 765 cm^{-1} for Si-O-Si, 1145 cm^{-1} for Si-O- , 1020 cm^{-1} for Si (Al)-O- , 730 cm^{-1} for Si-O-Al, 610 cm^{-1} for –O-Si(Al) –O- and Ca-O-, 400-500 cm^{-1} for Si-O-Mg; Si-O-Fe; Si-O-Al bonds in different minerals.

The mineral oxide and mineral elemental composition of coal ash of the 3 coal deposits, based on the X-Ray Fluorescence spectrum, are given in Table 4.

Table 4. Mineral oxide and mineral elemental composition of coal ash from the three sample coal deposits

№	Content	Tavan-tolgoi	Baganuur	Shariin Gol	Content	Tavan-tolgoi	Baganuur	Shariin Gol
	Oxides,%				Elements,%			
1	Na_2O	-	-	-	Na	-	-	-
2	MgO	-	2.66	4.50	Mg	-	1.60	2.70
3	Al_2O_3	15.75	6.22	19.90	Al	8.33	0.29	10.50
4	SiO_2	77.61	24.19	19.90	Si	36.28	11.30	21.10
5	SO_3	1.93	7.23	1.60	S	0.77	2.89	0.63
6	K_2O	0.52	0.96	2.40	K	0.43	0.80	2.00
7	CaO	1.89	40.38	4.23	Ca	1.35	28.86	3.70
8	TiO_2	0.92	1.18	3.80	Ti	0.55	0.71	2.30
9	V_2O_5	-	0.02	-	V	-	0.05	-
10	Mn_2O_3	-	0.30	-	Mn	-	0.21	-
11	Fe_2O_3	0.72	17.36	16.70	Fe	0.50	12.15	11.70
12	CuO	0.01	0.11	-	Cu	0.01	0.03	-
13	SrO	0.03	0.27	0.27	Sr	0.02	0.22	0.23
14	NiO	0.01	0.10	0.09	Ni	0.08	0.01	-
15	ZrO_2	-	0.03	0.07	Zr	-	0,03	0.05
16	PbO	-	0.03	0.37	Pb	-	0.11	0.34
17	P_2O_5	0.58	-	-	P	0.25	-	-
18	ZnO	-	-	0.09	Zn	0.02	-	0.07

$*(Fe_2O_3 + CaO + MgO + Na_2O + K_2O) / (SiO_2 + AI_2O_3 + TiO_2)$ acidic < 1 < alkaline

The data in Table 4 show that the main components of all ash samples are SiO_2, AI_2O_3, CaO, and Fe_2O_3. The content of CaO and Fe_2O_3 is lowest in the ash of Tavantolgoi coal. The content of both AI_2O_3 and CaO is lower in the ash from the Sakhan Ovoo mine. The content of SiO_2 is highest in the ash of Tavantolgoi coal, and the content of Fe_2O_3 is highest in the ash of Sakhan Ovoo coal. By using data in Table 4 we have calculated the ratio of $*(Fe_2O_3 + CaO + MgO + Na_2O + K_2O) / (SiO_2 + AI_2O_3 + TiO_2)$. The estimaed values of ratio are given in Table 5.

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Table 5. The calculated ratio of (Fe_2O_3 + CaO + MgO + Na_2O + K_2O) / (SiO_2 + AI_2O_3 + TiO_2) and character of coal ash.

№	Coal deposit	(Fe_2O_3 + CaO + MgO + Na_2O + K_2O)/(SiO_2 + AI_2O_3 + TiO_2)	Type of ash
1	Tavantolgoi	0.03	acidic
2	Baganuur	1.25	alkaline
3	Shariin Gol	0.63	acidic

The calculated values of the ratio between (Fe_2O_3 + CaO + MgO + Na_2O + K_2O) and (SiO_2 + AI_2O_3 + TiO_2) show that the ash of Tavantolgoi coal is acidic, the ash of Baganuur coal is alkaline and the ash of Shariin Gol coal is acidic as well.

In the X-Ray rentgenphash spectrum of ash of the coal samples from Tavantolgoi, Baganuur and Shariin Gol deposits in the most intensive four signals belong to such minerals as quartz, anhydrite, akermanite and albite. The chemical formulae of these determined four minerals are given in Table 6.

Table 6. Most determined minerals in the sample coal ash

Ash of coal samples from	Most determined minerals in the coal ash	Chemical Formule
Tavantolgoi, Baganuur and Shariin Gol,	Quartz	SiO_2
	Anhydrite	$CaSO_4$
	Akermanite	$Ca_2(Mg_{0.75}Al_{0.25})(S_{4.75}Al_{0.25})O_7$
	Albite	$Na(S_3Al)O_8$

The results of pyrolysis (carbonization) experiments of the three types of coals are given in Table 7.

Table 7. The yields of pyrolysis products of coal samples

№	Coal deposit	Hard residue, %	Tar, %	Pyrolysis water, %	Gas, %
1	Tavantolgoi	80.60	6.55	1.59	11.26
2	Baganuur	68.31	8.71	7.14	15.84
3	Shariin Ggol	70.04	5.68	10.78	13.50

The hard residue in Table 7 is the carbonized initial coal samples after pyrolysis (carbonization).The yields of pyrolysis products such as tar, pyrolysis water and gas of the three coal samples are different in Table 7. The yield of pyrolysis hard residue (carbonized coal is the main product) is higher for the Tavantolgoi coal because of it‘s higher rank and better thermostability of organic matter.

The yield of pyrolysis hard residue is lower in the case of Shariin Gol and Baganuur coals, which are low rank coals (in comparison with Tavantolgoi) with lower thermal stability of organic matters. Thermal decomposition of the organic matter of the coal occurred during the carbonization (pyrolysis) of coals and we obtained a condensed liquid (tar and pyrolysis water) and uncondensed gas

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products during the pyrolysis. Therefore, the obtained hard residue (carbonized coal) has a visible porous material with mezo and macro pores. It is possible that some pores are filled with volatile matters, which did not escape fully during pyrolysis. In order to obtain a good quality adsorbent material with a highly developed porosity structure it is necessary to have an additional processing such as purification of coal, and carbonization and activation of the obtained hard residue with preheated water steam, in order for the porosity of the pyrolysis hard residue to increase after the activation.

For this very reason we prepared the three coal samples for purification in heavy liquid. The content of moisture and ash (decreasing of ash content is most important) of these samples were determined and the results are given in Table 8.

Table 8. The content of moisture and ash of coal samples for purification

№	Coal deposit	W^a, %	A^a, %	A^d, %
1	Tavantolgoi	0.77	8.21	8.30
2	Baganuur	7.39	8.52	9.20
3	Shariin Gol	5.63	7.72	8.20

The yields of fractions of coal samples in heavy liquid purification are given in Table 9.

Table 9. The results of enrichment of coals in heavy liquid

№	Coal deposit	Weight of coal sample, g	The yield of upper fraction, %	The yield of bottom fraction, %	Loss, %
1	Tavantolgoi	753.10	82.60	12.00	5.40
2	Baganuur	885.70	48.49	44.48	6.90
3	Shariin Gol	848.40	72.40	10.69	16.85

The results of enrichment for yields of upper (purified coal) and bottom (mineral matter) fractions are different as can be seen in Table 9. For example, Tavantolgoi coal has the highest yield of upper fraction. Usually higher rank coals, such as the Tavantolgoi and Shariin Gol coals have higher yield of upper fraction and the lower rank coal of Baganuur deposit has a lower yield of upper fraction. The loss in percentage as shown in Table 6 means that some particles of coal and mineral matter are dispersed in the middle zone between upper and bottom fractions. The determined content of moisture and ash of coals samples (purified) of upper fraction are given in Table 10.

Table 10. Technical characteristics of coals (upper fraction) after enrichment

№	Coal deposit	W^a, %	A^a, %	A^d, %
1	Tavantolgoi	0.74	4.74	4.80 (8.30)
2	Baganuur	8.10	7.80	7.30 (13.00)
3	Shariin Gol	5.61	6.48	6.90 (8.20)

( )-ash content of initial coal samples for comparison

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The content of ash of purified coals in Table 10 compared with ash of coals before the purfication show that the mineral matter content of coal from Tavantolgoi deposit after enrichment is decreased significantly by almost 2 times, and in the case of Baganuur and Shariin Gol coals the ash content decreased from 20 to 30 percent in comparison with the ash content of initial coal samples.

The purified coal samples from these three deposits have been tested for a pyrolysis (carbonization) experiments in a bigger scale retort designed by us and the pyrolysis products yield, including hard residue, condensed liquid (tar) and uncondensed gas have been determined and the results of which are given in Table 11.

Table 11. The yields of pyrolysis products of purified coal samples after enrichment

№	Sample	Hard residue,%	[1]Tar +Pyrolysis water,%	Gas,%
1	Tavantolgoi	82.70	4.77	12.53
2	Baganuur	68.50	15.75	15.75
3	Shariin Gol	71.10	16.70	12.20

Note[1] in this experiment the yield of tar and pyrolysis water has been determined together (not separated).

The hard residue in Table 11 is the carbonized purified coal samples after pyrolysis (carbonization). The yields of pyrolysis products, such as tar with pyrolysis water and gas are different in Table 11. The yeilds of pyrolysis hard residue are higher in comparison with the yield of pyrolysis hard residue of initial coal samples (Table 12). We had expected this result because the ash content of all initial coal samples were decreased almost twice by enrichment in heavy liquid of $ZnCl_2$ solution.

As was mentioned above, in order to increase the porosity of the hard residue after pyrolysis of purified coal samples, we treated the coal samples with preheated water steam activation as described in the experiment section.

The technical characteristics of activated carbon samples were determined, which are given in Table 12.

Table 12. The results of technical analysis of activated carbon samples after activation of pyrolysis hard residue at 800°C by water steam.

№	Activated carbon from	Time of activation, min.	Yield, %	Moisture, W^a, %	Ash, A^d,%	Volatile matter, V^{daf}, %	Gas, %
1	Tavantolgoi	120	77.12	0.67	8.03	2.60	11.58
2	Baganuur	120	54.01	0.27	14.40	6.00	25.33
3	Shariin Gol	120	56.80	0.24	13.30	2.90	26.76

The yield of activated carbon from Tavantolgoi coal is higher than others because of their higher degree of purification and higher thermal stability. The yield of activated carbon is lower in Table 12 than in Table 13, because the pyrolysis (carbonization) of purified coal samples was carried out at a temperature of 700°C (Table 8) and the activation of carbonized samples was carried out at a temperature of 800°C. At this higher temperature, the organic matter of carbonized hard residue can be decomposed and also the pores, which had been filled in by volatile matters, can be opened during

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activation with preheated water steam.

The important technical characteristics of activated carbons is the adsorption propertie and the deternination of iodine and methylene blue adsorption by chemical analysis, which are also the most common method used and are easier methods for the characterization of activated carbons.

And therefore, the prepared activated carbon samples and pyrolysis hard residue of initial coal samples without activation (for comparison) were analyzed for iodine and methylene blue adsorption to evaluate the adsorption capacity and the results are given in Table 13.

Table 13. The determined iodine number and methylene blue adsorption of activated carbon samples

№	Coal deposit	Type of sample	Iodine number, %	Methylene blue adsorption, mg/g
1	Tavan-tolgoi	Pyrolysis hard residue of initial coal sample	3.30	1.40
		Activated carbon of purified and carbonized coal	16.54	6.00
2	Baganuur	Pyrolysis hard residue of initial coal sample	1.50	0.60
		Activated carbon of purified and carbonized coal	14.06	4.10
3	Shariin Gol	Pyrolysis hard residue of initial coal sample	1.80	1.00
		Activated carbon of purified and carbonized coal	15.00	5.10

Table 13 clearly shows that the determined iodine number of activated carbon of purified and carbonized coals had increased by 5-17 times and methylene blue adsorptions are also increased 4-10 folds, as compared with pyrolysis hard residue of initial coal samples, which were not purified and not activated. The activated carbon samples prepared from Tavantolgoi coal has higher adsorption ability than that of Shariin Gol and Baganuur coals, because as was mentioned above, Tavantolgoi coal is of higher rank and is of higher quality than that of brown coal and anthracite. The other important technical specification of activated carbons is the determination of surface area (BET). For this reason, we determined the surface area (BET) of prepared activated carbon and initial coal samples to show how purification, carbonization and activation of initial coal samples can impact the developing of surface area (BET) of prepared activated carbons of each coal deposits including from Tavantolgoi (Fig.6), Baganuur (Fig. 7) and Shariin Gol (Fig. 8).

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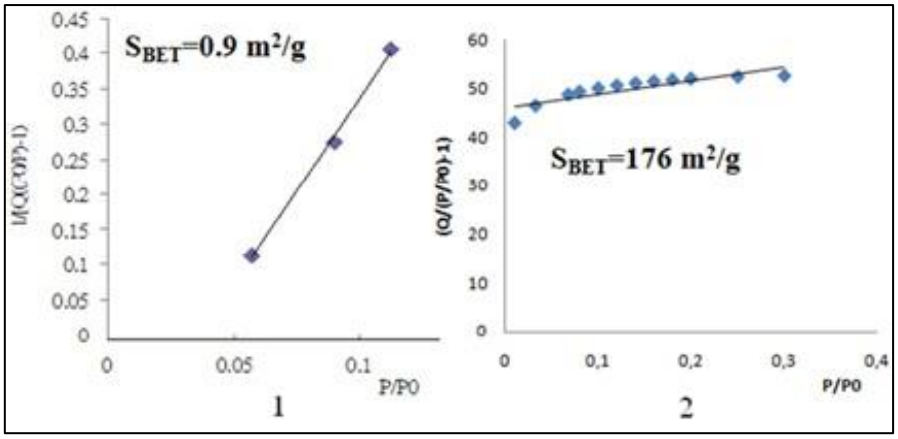

Figure 6. The surface area (BET) determination analysis of initial coal (1) and it's activated carbon (2) samples of the Tavantolgoi coal deposit

The surface area (BET) determination results of initial coal (1) and it's activated carbon (2) samples of the Tavantolgoi coal deposit in Fig. 6 show that the surface area of the cativated carbon is 195 times higher than that of original coal of the Tavantolgoi deposit.

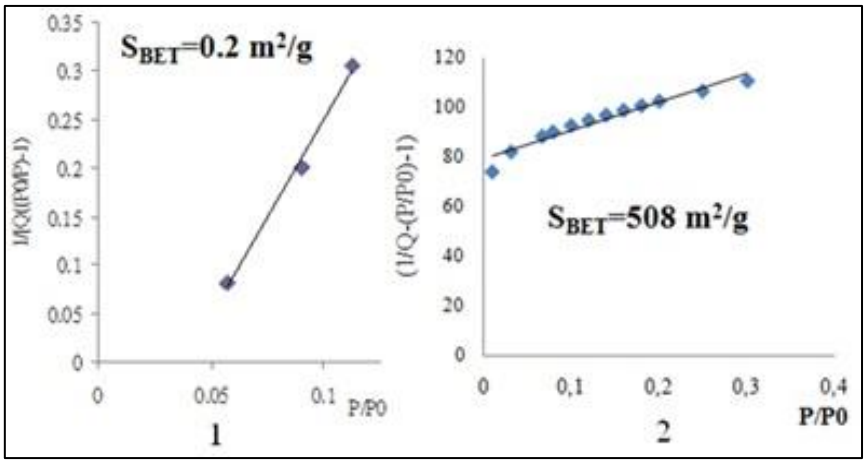

Figure 7. The surface area (BET) determination analysis of initial coal (1) and it's activated carbon (2) samples of the Baganuur coal deposit

The surface area (BET) determination results of initial coal (1) and it's activated carbon (2) samples of the Baganuur coal deposit in Fig. 7 show that the surface area of the cativated carbon is 2540 times higher than that of initial coal of the Baganuur deposit.

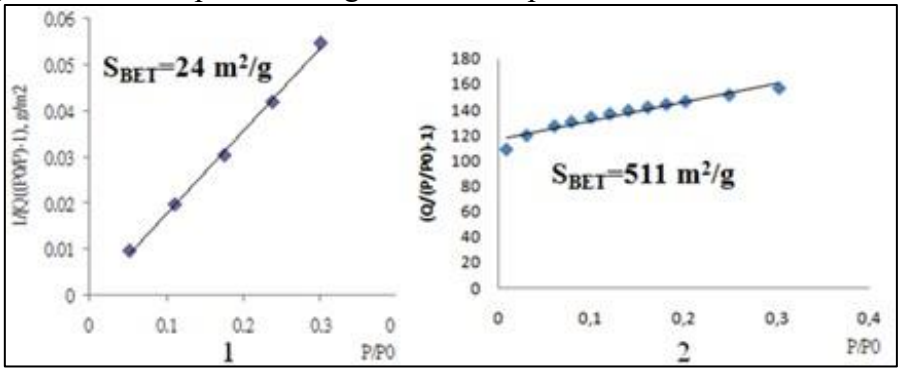

Figure 8. The surface area (BET) determination analysis of initial coal (1) and it's activated carbon (2) samples of the Shariin Gol coal deposit

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The surface area (BET) determination results of initial coal (1) and it's activated carbon (2) samples of the Shariin Gol coal deposit in Fig. 8 show that the surface area of the cativated carbon is 21 times higher than that of initial coal of the Shariin Gol deposit.

As a result all investigation on characterization and preparation of activated carbons from the three coal deposits with different coal rank and quality in the different regions of Mongolia, we have been able to work out a reasonable technological scheme for production of coal-derived activated carbon, which is shown in Fig.9.

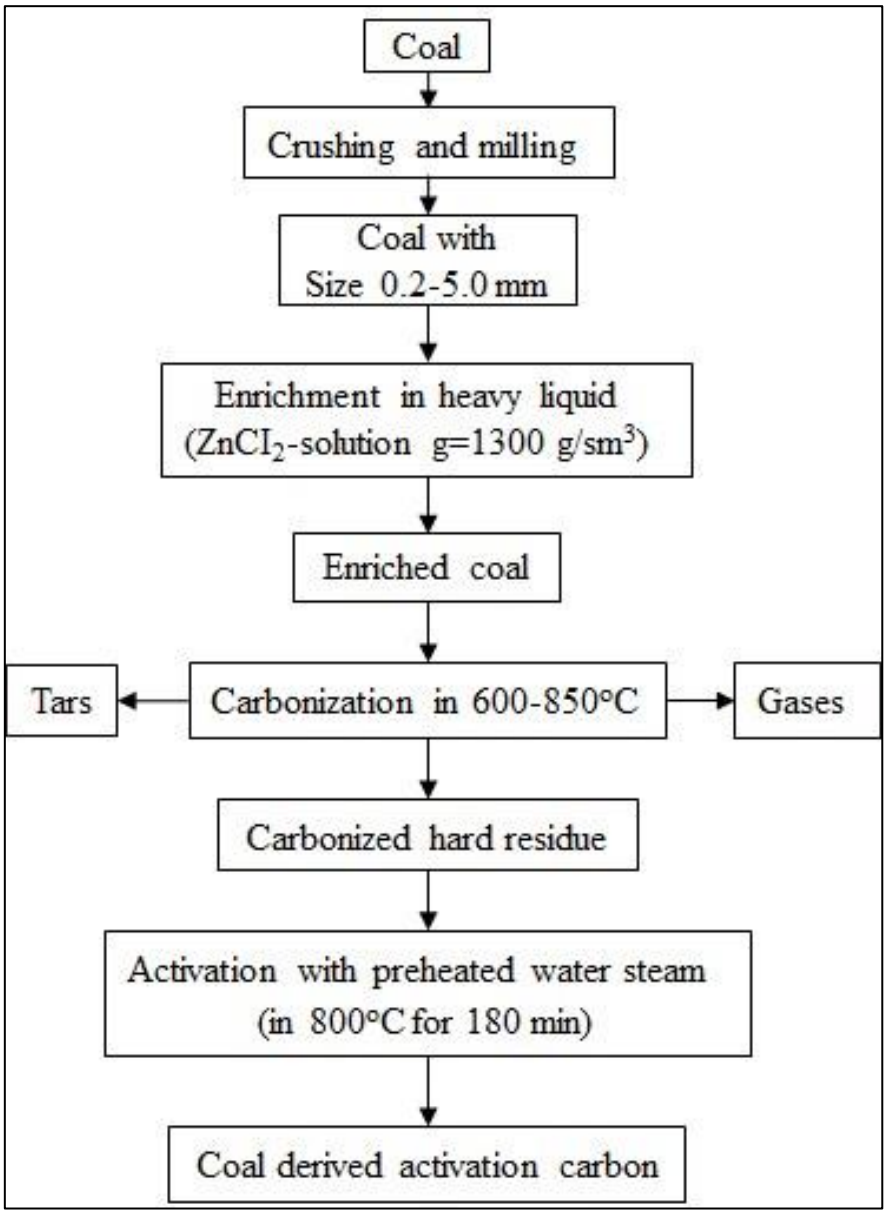

Figure 9. Technological scheme for production of coal-derived activated carbon

The technological scheme for production of coal-derived activated carbon consists of four important steps, such as, crushing and milling, enrichment in heavy liquid, carbonization and activation with preheated water steam.

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CONCLUSIONS

1. Coals from Baganuur, Shariin Gol, and Tavantolgoi deposits have been evalueted on the basis of ultimate and proximate analysis according to international classification of coals as follows:
   a. The Tavantolgoi coal is a high rank bituminous coking coal of KZh mark,
   b. The Baganuur coal is an oxidized brown and lignite type coal of B2 mark,
   c. The Shariin Gol coal is stone sub-bituminous coal.
2. The yield of pyrolysis hard residue (carbonized coal) is higher for the Tavantolgoi coal, because of it's higher rank and more thermostability of organic matter. The obtained hard residue (carbonizded coal) has a visible porous material with mezo and macro pores. It is possible that some pores are covered (filled in with) by volatile matters, which could not fully escape during pyrolysis. In order to obtain a good quality adsorbent material with high developed porosity structure it is necessary to have an additional processing, such as purification of coal, carbonization and activation of the obtained hard residue with heated water steam.
3. The content of ash of coal, purified in heavy liquid of $ZnCl_2$ solution, compared with ash of coals before purification, show that the mineral content of coals after enrichment decreases significantly, almost twice in all samples.
4. On the basis of carbonization, purification and activation experiments of coal samples, we have been able to work out a reasonable technological scheme for production of coal-derived activated carbons with high developed porosity structure.
5. The determined iodine number of activated carbons of purified and carbonized coals increased 5 to 17 times and methylene blue adsorptions also increased by 4-10 times as compared to the of pyrolysis of hard residue of initial coal samples without purification and activation.
6. The activated carbon samples prepared from Tavantolgoi coal has higher adsorption capacity than that of Shariin Gol and Baganuur coals, because, as mentioned above, these coals are high rank and are of higher quality than other types of coal.
7. On the basis of the experiments carried out with the preparation and characterization of activated carbons from coals of Tavantolgoi, Shariin Gol and Baganuur deposits, we have worked out a reasonable technological scheme for the production of coal-derived activated carbon.

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