**Sorbent Carbon Development
Task 5.2**

**Topical Report
January 1994 - June 1995**

Ronald C. Timpe

November 1995

Work Performed Under Contract No.: DE-FC21-93MC30097

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
University of North Dakota
Grand Forks, North Dakota

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Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
University of North Dakota
Energy & Environmental Research Center
P.O. Box 9018
Grand Forks, North Dakota 58202-9018

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TASK 5.2 SORBENT CARBON DEVELOPMENT

1.0 INTRODUCTION

Chars and other carbons, in granular or powdered form, are in high demand worldwide for environmental applications associated with energy production and by-product recovery. Carbons for gas-phase cleanup (sulfur gases, NO_x , and trace element removal) and liquid-phase cleanup (organics removal) sell for several hundred to several thousand dollars per ton, depending upon grade and end use. In general, these carbons have undergone an activation process, i.e., steam or CO_2 . Commercial sorbent carbons are derived largely from coal and biomass sources such as coconut shells and wood. Bituminous coals have been typically used for producing hard, large-pore-volume carbons for gas and vapor applications. Lignite carbons, with a hard, small-pore-volume texture, have been preferred in wastewater treatment. Information on the relative effectiveness of bituminous and lignite coal carbons is not readily available. Also, information is needed on the extent to which various preparation and metal ion impregnation procedures can alter structure, gas sorption capacity, and selectivity to develop low-cost supersorbents. Hence the need exists to develop methods to demonstrate the feasibility of utilizing lignites and allied materials (e.g., leonardite) as effective gas or vapor sorbents.

Activated carbon is used as an adsorbent in all aspects of fluids cleanup, including acid gas and toxic trace metals removal from combustion flue gases resulting from electrical generation and waste incineration, removal of heavy metal and organic contaminants of water, and removal of organic vapors from liquid fuel systems to prevent volatile organic emissions (VOCs). The cost of activated carbon produced from traditional feeds such as coconut shells, bones, and other carbonaceous material becomes prohibitive in the quantities required to satisfy all of these needs. An obvious substitute for these feeds is coal, which, because of its large reserves and availability, makes a much less expensive carbon source. Pyrolysis of coal, followed by activation with a reactant gas, has been shown to produce a satisfactory substitute for the activated carbon produced from the previously mentioned activated feedstocks. North Dakota has large reserves of lignite and leonardite (naturally weathered lignite) from which a useful activated carbon product (char) can potentially be manufactured. This project is directed toward producing activated carbon from a leonardite and lignite optimized for specific applications in gas and water cleanup.

2.0 OBJECTIVES

The primary objective of this study is to transform low-rank coals (LRCs) into effective sorbent carbons economically for gas- and liquid-phase contaminant removal.

Specific objectives for 1994 are detailed as follows:.

- To determine the relative ranking of powdered and granulated carbons prepared from a lignite or leonardite with those of commercial carbons derived from bituminous coals or other raw materials for the sorption of sulfur-containing gases and mercury.

- To examine the effect of coal properties (e.g., rank, chemistry, ash content, and composition), metal ion impregnation, and carbon preparation and granulation (size enlargement) on gas-phase adsorption properties.

3.0 EXPERIMENTAL

3.1 Equipment

The activated carbon preparations were carried out on milligram, gram, and kilogram quantities of feed material. They were typically performed in two steps, i.e., a carbonization step followed by an activation step. A brief description of the reactors used for preparing the carbons follows.

3.1.1 Small TGA

Preliminary parametric studies of preparation of activated char from LRCs were carried on a TA Instruments 951 thermogravimetric analyzer (TGA) interfaced with a model 2100 controller/data station. Approximately 50 mg of the coal was carbonized by heating to a target temperature (usually 480°C) under inert atmosphere and holding at that temperature for a predetermined period of time. The sample was then activated by heating at a second target temperature under inert gas or inert gas followed by steam for a second predetermined period of time. The char was then characterized by SO₂ adsorption and, in selected cases, by proximate analysis.

3.1.2 Large TGA

A large-capacity TGA was built at the Energy & Environmental Research Center (EERC) to carry out TGA experiments with larger quantities of material. The unit was built using a Cahn 1000 electrobalance and temperature controller and is interfaced to a microcomputer. In this study, the sample (limited by sample bulk) was loaded into a high-temperature stainless steel wire mesh basket, heated at 30°C/min in a flowing N₂ gas stream to target temperatures of 700°, 750°, 800°, or 850°C, and reacted with steam. Higher temperatures are not available on this instrument, so a tube furnace was used for activation at the higher temperatures.

3.1.3 Tube Furnace (TF)

A Lindberg Type 59344 TF was used to activate the char at temperatures of 800°, 850°, 900°, 950°, and 1000°C after carbonization. The heating chamber is 19 in. long and accommodated the 1-in.-OD Vycor tube, which was used as the reactor vessel when the char was activated.

3.1.4 Kiln Reactor

A new reactor used for carbonizing or carbonizing and activating feedstock is first described. The kiln reactor was assembled from a Cress Model X31TC kiln containing a stainless steel cylindrical vessel wrapped on the outside with stainless tubing. The kiln is rated for 2500°F (1370°C). The vessel, which has a capacity of 2700 in.³ (44,480 cm³), is designed to be operated in the fixed-bed mode. It has a distributor plate on the bottom through which gas, preheated by the kiln as it passes through the external coils on the vessel, enters to permeate the coal bed. The tars, oils,

moisture, and effluent gases exit through the top of the vessel and pass through a series of two air-cooled condensers before being vented to the outside of the building.

3.2 Feed Material

The work carried out in this project primarily involved $-12 \times +30$ -mesh North Dakota leonardite, a highly oxygenated LRC. The ash content of the Georesources leonardite, the principal char source, was significantly higher than expected, as shown in Table 1. Moisture-free ash was 28 wt% as compared to 15 wt% in the leonardite from the same source as obtained in 1991, the latter being one of the two best SO_2 sorbents in a suite of 18 coals tested in a preliminary screening of LRCs for char sorbent preparation. Because of the disparity in gross composition between this lot and the 1991 lot, proximate analysis was carried out on samples of raw Georesources leonardite and on raw Gascoyne leonardite, also from North Dakota, as well as x-ray fractionation (XRF) analysis on the ash of the leonardites. The results of these analyses are shown in Tables 1 and 2, respectively. Reduction of ash content was partially accomplished by grinding the coal and preparing the activated carbon from the -12×30 -mesh fraction.

3.3 Test Plan - Sorbent Preparation and Testing

Preliminary carbon preparation testing was carried out on the small TGA. The sample was carbonized at one temperature (250° , 350° , 480° or 550°C) under inert gas for selected time, then activated at a higher temperature (700° – 1000°C) under inert or reactive gas for a selected time, then cooled. The resulting carbon was characterized by SO_2 adsorption at ambient temperature or 100°C . Conditions for carbon preparation at a larger scale were selected based on the results of the tests carried out on the small TGA and are shown in Table 3.

The activated chars prepared on a larger scale were characterized using the following:

- TGA proximate analysis
- SO_2 sorption at ambient temperature
- Iodine number
- BET surface area (selected samples)
- Porosity (selected samples)

TABLE 1

Proximate Analysis of Two North Dakota Leonardites

	Georesources Leonardite		Gascoyne Leonardite	
	As-Received	Moisture-Free	As-Received	Moisture-Free
Moisture, wt%	32.6	–	42.1	–
Volatiles, wt%	29.8	44.1	28.6	490.4
Fixed Carbon, wt%	18.6	27.6	21.6	37.2
Ash, wt%	19.1	28.3	7.0	12.0

TABLE 2

XRF Analysis of Georesources Leonardite and Gascoyne Leonardite Ash

	Georesources Leonardite			Gascoyne Leonardite		
	Ash as Element, wt %	Ash as Oxide, wt %	Coal as Element, wt %	Ash as Element, wt %	Ash as Oxide, wt %	Coal as Element, wt %
Silica, SiO ₂	12.8	27.4	3.6	9.7	20.8	1.2
Aluminum Oxide	8.1	15.4	2.3	6.5	12.2	0.8
Ferric Oxide	4.8	6.9	1.4	9.6	13.7	1.2
Titanium Oxide	0.3	0.5	0.1	0.3	0.5	-
Phosphorus Pentoxide	0.1	0.3	-	0.1	0.2	-
Calcium Oxide	11.8	16.5	3.3	14.1	19.8	1.7
Magnesium Oxide	4.5	7.4	1.3	6.4	10.7	0.8
Sodium Oxide	0.6	0.8	0.2	0.7	0.9	0.1
Potassium Oxide	0.6	0.7	0.2	0.3	0.4	-
Sulfur Trioxide	8.8	22.0	2.5	6.6	16.4	0.8
Total	52.4	97.8	14.9	54.3	95.5	6.5

3.4 Physical Cleaning of Leonardite

Washability testing was performed on raw leonardite using Certigrav at specific gravity 1.4 and 1.6. The float fractions were carbonized at 480°C under N₂ and activated at 750°C under steam on the small TGA. The carbon was characterized with SO₂ adsorption.

Two hundred ninety pounds of +3-mesh leonardite was cleaned by density separation using a dense medium (magnetite). The float fraction recovered weighed 169 pounds. Twelve kilograms of the float fraction from the dense-media separation was carbonized in the kiln reactor at temperatures of 480°C and 350°C under flowing N₂. Each carbonized fraction was activated at 750°C under steam.

3.5 Chemical Cleaning

The mineral content of the leonardite is quite high as indicated by the proximate analysis shown in Table 1. A sample of leonardite was washed with hot 4.8 M HCl, in a manner similar to that prescribed in the ASTM D2492 for removal of pyrite from coal. A second sample was chemically cleaned with HCl followed by a cleaning with HF. The chemically cleaned samples were washed thoroughly to remove residual acid and water soluble salts and dried at 105°C under flowing N₂ gas. Proximate analyses were carried on the chemically cleaned leonardite and the results are shown in Table 4. The chemically cleaned leonardite samples were then carbonized and activated for 60 minutes under steam in a vertical tube reactor.

TABLE 3

Activation Conditions for Leonardite Carbonized at 480°C - Test Plan 1

Test No.	Sample Size, g	Reactor	Atmosphere	Temperature, °C	Time, min
1	10	TGA	N ₂	700	10
2	10	TGA	N ₂	750	10
3	10	TGA	N ₂	800	10
4	10	TGA	N ₂	850	10
5	50	TF	N ₂	800	10
6	50	TF	N ₂	850	10
7	50	TF	N ₂	900	10
8	50	TF	N ₂	950	10
9	50	TF	N ₂	1000	10
10	12000	Kiln	N ₂	750	60
11	12000	Kiln	N ₂ /H ₂ O	750	60

3.6 Physical Measurements on Activated Chars

Surface areas were determined according to the Brunauer-Emmett-Teller (BET) technique using N₂ as the adsorbate. Bulk volume was determined by Hg displacement using a Ruska mercury porometer. Pore volume was determined using the same instrument and pressurizing to an instrument standard of 750 psig.

4.0 RESULTS

4.1 Effect of Activation Temperature

Properties of the char produced from leonardite according to the test plan are illustrated in Figures 1-5. Figure 1 shows the proximate analysis of raw leonardite, leonardite carbonized at 480°C, and carbonized leonardite, i.e., leonardite char, activated with steam at temperatures from 700° to 1000°C in 50°C intervals. The only trend seen in the figure is a decrease in volatiles. These volatiles at the higher temperature are probably not indigenous to the coal, but are surface-adsorbed gases occurring on exposure of the activated char to air. This being the case, the lower level of volatiles implies a less active char carbon.

TABLE 4

Proximate Analysis of As-Received Raw Leonardite, Leonardite Char Carbonized under N₂ at 480°C and Activated at 750°C, and Chemically Cleaned Leonardite.

Treatment	Atmosphere	Time, min	Moisture, wt% as-rec'd.	Volatile Matter, wt% moisture-free	Fixed Carbon, wt% moisture-free	Ash, wt% moisture-free
Raw	-	-	32.6	44.1	27.6	28.3
Raw	Steam	20	1.0	8.5	53.7	37.9
HCl Leach	Steam	60	0.9	48.3	44.9	6.8
HCl, HF Leach	Steam	60	7.0	51.5	48.1	0.4

Figure 1. Proximate analysis of raw leonardite, leonardite carbonized at 480°C, and steam-activated carbonized leonardite.

Figure 2. SO₂ adsorption from flowing gas containing 5000 ppm SO₂ in argon at ambient temperature. Chars activated at 700°, 750°, and 850°C have similar sorption capacities when tested at ambient temperature.

Figure 3. SO₂ adsorption from 5000 ppm SO₂ in argon at 100°C.

Figure 4. Ratio of SO₂ sorption capacity at ambient temperature to sorption capacity at 100°C versus steam activation temperature.

Figure 5. Sorptive capacity for I₂ of chars steam-activated at increasing temperatures.

Figure 2 shows SO₂ adsorption at ambient temperature by leonardite char activated at several temperatures. The char produced at 850°C shows the greatest SO₂ sorption capacity of those produced in the TF. At activation temperatures higher than 850°C, a decrease in activity with increasing activation temperature is noted. The char activated at 800°C in the TGA shows the highest SO₂ sorption capacity of those activated.

Figure 3 shows SO₂ adsorption at 100°C. Char activated in the TGA shows maximum sorption capacity at 750°C followed by decreasing capacity with increasing temperature. Similarly, the char activated in the TF had a maximum at 850°C followed by a slight decrease with temperatures up to 900°C and then a rapid decrease in sorption capacity up to 1000°C.

Since Figures 2 and 3 showed similar trends but apparently differed by a constant, the ratio of the SO₂ adsorption values at the two temperatures was plotted against activation temperature. Figure 4 shows the near linearity, with a slope of 0.0012/°C. For this set of tests, SO₂ adsorption can be predicted with reasonable accuracy using the following equation:

$$\%_{\text{Amb}} \text{SO}_2 = 2.79 \times \%_{100^\circ\text{C}}$$

Figure 5 shows iodine adsorption as a function of activation temperature. The trend of iodine adsorption for the samples activated in the TF is similar to the SO₂ sorption behavior, but those of the samples activated in the TGA exhibit a much steeper slope than those of the TF. However, for SO₂, the slope of the TGA curve was markedly less than that of the TF samples. It appears from this limited data set that the iodine number gives a sharper focus with regard to optimum conditions for maximum sorption than does the SO₂ sorptive capacity. The maximum values of the iodine number occurred on chars prepared in the TGA at 750°C and in the TF at 800°C. These are the same activation temperatures that produced the chars having the maximum SO₂ sorption capacities when SO₂ adsorption was measured at 100°C. Nevertheless, the maximum SO₂ capacities measured at ambient temperature occurred on chars activated at 800°C (TGA) and 850°C (TF), i.e., chars activated at temperatures 50°C higher than those giving maximum SO₂ capacity when measured at 100°C or maximum iodine number. The iodine numbers calculated from single point determinations, which should lie between 600 and 1450 mg I₂/g C for a commercial active carbon, ranged between 320 and 460 mg I₂/g char for the leonardite char.

Sorbent prepared from German brown coal by the method of Stadtwerke Dusseldorf was expected to adsorb up to 16 wt% SO₂, but in practice actually adsorbed 10–12 wt% (1). Marnet, et al. (2) gave similar properties for lignite char and gave SO₂-loading values for the sorbent of 10–15 wt%. GE-Mitsui-BF produces an activated coke that has a sorptive capacity of 6%–12%, with a BET surface area of 150–250 m²/g (3). By comparison, leonardite char with its high mineral content adsorbed less SO₂ than the German or Mitsui chars, but adsorbance by cleaned leonardite was much improved. The BET surface area of the cleaned leonardite was higher than either of the chars mentioned. Additional discussion of these results is found in Section 4.4.

4.2 Effect of Physical Cleaning

Silicon, aluminum, iron, and calcium metals make up the major portion of the ash of the Georesources and Gascoyne leonardites (72 and 74 wt% of the oxygen-free weight in the ash, respectively), but the total weight of these four elements is more than twice as great in the Georesources as in the Gascoyne leonardite (10.6 vs. 4.8 wt%). At activation temperatures above

the calcination temperature, the calcium may be converted to calcium oxide, which may be beneficial for trapping SO₂ but also deactivates easily at low temperatures in the presence of high concentrations of CO₂. The weight percent of elemental sulfur is greater than 16 wt% of the oxygen-free Georesources leonardite ash and greater than 12 wt% of the oxygen-free Gascoyne leonardite ash (this may be beneficial for trapping mercury). Ultimately, however, it may prove beneficial to remove as much of the ash as is feasible before making the activated char for sorbent use.

Washability testing was performed on raw leonardite with Certigrav specific gravity 1.4 and 1.6 and leonardite char which had been prepared in the kiln reactor at 450°C under flowing N₂ at specific gravity 1.6. The results of proximate analyses of the sink-float fractions are shown in Table 5. The washability results, shown in Table 6, indicate that physical cleaning will reduce the ash in either the raw or carbonized leonardite by more than 55%, with 72%–75% recovery of the feed (dry basis) in the float fraction.

TABLE 5

Proximate Analysis of Georesources Leonardite Sink-Float Fractions

Fraction	Moisture, as-received, wt %	Volatile Matter, moisture-free, wt %	Fixed Carbon, moisture-free, wt %	Ash, moisture-free, wt %
Float 1.6	22.3	38.4	51.7	9.9
Sink 1.6	6.1	29.4	13.2	56.7
Float 1.4	42.9	51.2	41.8	7.0
Sink 1.4	15.8	29.0	13.3	57.6

TABLE 6

Ash Reduction and Solids Recovery from Washability Testing of Leonardite

	Specific Gravity	Weight, g	Solids, wt %	Dry, g	Solids Recovery, wt %	Ash, wt %	Ash Reduction, %
Raw	–	150.0	64	96.5	–	22	–
Float	1.40	112.8	60	68.0	72	9	56
Sink	1.40	31.7	83	26.2	28	54	–
Char (K3)	–	150.0	93	140.2	–	24	–
Float	1.60	112.8	92	104.1	75	11	55
Sink	1.60	36.8	96	35.4	25	62	–

4.3 Effect of Chemical Cleaning

Mineral matter content and its alkaline nature are two highly variable properties that can have important consequences on the production of suitable activated carbons. Lignite-based activated carbons typically have a low micropore volume, some 17% of the pores being micropores versus 35%–50% macropores (4). The macropores contribute little to surface area and hence have a small impact on the adsorption process. Samaras, Diamadopoulos, and Sakellaropoulos (5) have recently shown that the removal of mineral matter improves the micropore volume of activated carbons since the mineral matter catalyzes the pyrolysis and carbonization reactions, leading to an enlargement of the pores. Several inorganic species, such as Fe, K, Mg, Ca, and Na are likely gasification catalysts, but the mechanism is not well understood. Removal of mineral matter, for example, from Spanish lignites (6), decreases the reactivity of the chars towards carbon dioxide and oxygen and produces random changes in the surface area as a result of structural changes (7). Davini (8) has recently demonstrated that carbons having a significant mineral matter content, particularly if an appreciable amount of iron is present, and an enhanced content of acidic oxygen groups have reduced capacity for SO_2 sorption.

The sorptive capacity of the activated char prepared from chemically cleaned leonardite was determined at ambient temperature and at 100°C for a 5000-ppm (5k) and a 10,000-ppm (10k) SO_2 atmosphere. The results are given in Table 7. Sorption testing with SO_2 was typically performed using a moisture-free SO_2 gas stream. Whereas cleaning the coal with HCl essentially removed the moisture-free SO_2 sorption properties from the leonardite, additional treatment with HF appeared to restore some of the activity. This may be explained by the high volatiles content of the char prepared from the cleaned leonardite as shown in Table 4 resulting from retention of moisture and chloride-blocking active sites, reducing the availability of active sites for adsorption of SO_2 . However, as seen in Table 7, an increase in adducted weight from the gas stream of more than 50% was noted when sorption occurred from an H_2O -saturated gas stream containing 5000 ppm SO_2 as compared with a dry SO_2 stream.

4.4 Surface Area and Porosity of Selected Samples

The surface area and porosity of selected samples of activated char prepared from coal were determined using N_2 BET and mercury porosimetry, respectively, as described above, and the results are shown in Tables 8 and 9. One experimental activated char prepared in Australia from a North Dakota lignite and KOH was tested along with the EERC chars and the commercial char (9). The Centaur activated char is a commercially available activated char prepared by a proprietary method from bituminous coal. The leonardite, physically and chemically cleaned leonardite, and lignite are North Dakota coals from which activated chars were prepared and characterized as described above.

The surface area is the total area available to adsorb N_2 , including internal surface of the particles. It was observed during these determinations that substantial moisture was evolved from North Dakota chars under vacuum, requiring extraordinary degassing time in order to remove the moisture and provide accurate measurement of surface area. The long degassing time required indicates large surface area in the form of small pores, implying a large surface area. As can be seen in Table 8, the surface areas of the Australian prepared char and the Centaur char were very high, making each an excellent candidate for sorption application. In addition, each adsorbed a substantial quantity of SO_2 but did not substantially retain it in the absence of reduced partial pressure of SO_2 in the gas stream, as shown in Table 9, making them candidates for regeneration. Although

TABLE 7

SO₂ Sorption by Char Prepared from Raw and Chemically Cleaned Leonardite Carbonized under N₂ at 480°C and Activated at 750°C.

Coal Treatment	Atmosphere	Time, min	Ambient (5k), wt%, maf ¹	100°C (5k), wt%, maf	Ambient (10k), wt%, maf
None	-	-	-	-	-
None	Steam	60	5.9	1.8	7.3
None	Steam	40	6.1	1.8	7.5
None	Steam	20	7.3	2.1	8.4
None	Steam	10	6.4	-	9.0
None	N ₂	0	7.1	-	9.2
HCl Leach	Steam	60	1.3	0.2	-
HCl, HF Leach	Steam	60	3.8	1.9	-
HCl, HF Leach	Steam	10	-	2.9 ²	-

¹Moisture- and ash-free.

²Adsorption from humidified gas.

TABLE 8

BET (N₂) Surface Area of Treated Leonardite and Other Experimental and Commercial Char

Sample	Surface Area, m ² /g
Leonardite-KOH	2.49
Acid-Cleaned Leonardite	390
1.6 Float Leonardite	445
Australian	920
Centaur	712

TABLE 9

Pore Structural Characterization of Commercial and North Dakota LRC Carbon				
	Centaur Char	Australian-KOH Char	ND Leonardite Char	ND Lignite Char
Moisture, as-received, wt%	2.9	3.0	1.1	4.7
Volatiles, moisture-free, wt%	1.4	3.8	8.4	13.4
Fixed Carbon, moisture- free, wt%	93.4	89.5	53.6	56.1
Ash, moisture-free, wt%	5.2	6.7	38.0	30.4
SO ₂ Adsorbed, Ambient, wt%	9.3	9.4	9.0	9.7
SO ₂ Desorbed, Ambient, wt%	5.6	7.6	4.2	2.1
SO ₂ Retained, wt%	3.7	1.8	4.8	7.6
Bulk Volume, cm ³ /g	1.32	1.30	1.25	1.28
Pore Volume, cm ³ /g	0.42	0.18	0.59	0.66
Density, g/cm ³	0.76	0.77	0.80	0.79
Porosity, (pore volume/bulk volume)	0.32	0.14	0.47	0.52

the surface areas of the chars prepared at the EERC were less than those prepared by the Australian process and the Centaur, they had more than twice the surface area of previous samples prepared from North Dakota coals. Adsorption of SO₂ by the EERC chars was as good as the Australian and Centaur chars but retention was 2 to 4 times that of the latter two. Calculated on a carbon basis, the SO₂ retention of the EERC leonardite char is 1.7 times as much SO₂ as the Centaur.

The bulk volume used to calculate porosity is the volume of the entire sample as determined by Hg displacement at ambient pressure. Some of the bulk volume may be porous, but void of Hg, since liquid Hg is excluded from all pores of diameter less than 14 μm (as defined by the Young-LaPlace theorem). The pore volume is described as that internal space having orifices less than 14 μm , which is grouped into macropores, mesopores, and micropores. As the Hg pressure is increased, the successively smaller pores are infiltrated with mercury.

If data from another analytical method supports the contention that small meso- and micropores are present in the sample, a small Hg porosity number indicates that the size of the pores tends

toward the smaller pore sizes. In principle, a pressure of 300,000 psig would force Hg into micropores of $< 5 \times 10^{-4} \mu\text{m}$ ($< 5 \text{ \AA}$) resulting in an accurate estimate of micropore volume although, in practice, this accuracy is of questionable value and is not possible with current equipment at the EERC.

5.0 SUMMARY

- Leonardite carbonized at 480°C produces char with highest SO₂ sorptive capacity and highest iodine number when activated with steam between 750° and 850°C.
- Reduction of inert mineral material (ash) in the leonardite (or carbonized leonardite) results in an increase in SO₂ uptake on a mg SO₂/g char basis.
- Measured differences in activity between chars activated at the same temperature in the TGA versus the TF probably result from differences in heating characteristics of the two reactor configurations; i.e., the sample in the TGA receives no heat via conduction from the reactor wall, resulting in more uniform sample heating than the sample in the TF, which is heated primarily by conduction from direct contact with the wall.
- The difference in SO₂ uptake at ambient temperature vs. 100°C is probably a result of the relatively large amount of physisorption occurring on the cooler surface caused by bonding that is too weak to retain the sorbate in the presence of increased thermal energy.
- German reports of char preparation show SO₂ uptake of 10%–15% at 70°–90°C. It is difficult to get the details of their measurement method to know exactly how our results compare, although their reported face values are at least a factor of 4 above the values we obtain at 100°C.
- BET surface area of physically cleaned North Dakota leonardite was approximately 440 m²/g and that of acid-cleaned North Dakota lignite was 390 m²/g, which are nearly twice as great as char prepared from raw coal tested previously. This indicates that presence of mineral material decreases surface area and the resulting adsorption capacity.
- 80% of adsorbed SO₂ is retained by the EERC North Dakota lignite activated char as compared with 40% of the Centaur char under conditions of reduced SO₂ partial pressure, indicating that chemisorption plays a greater role in the EERC lignite char than in the commercial char.
- Although the surface areas of the Centaur char and the Australian char are more than twice as great as those of the EERC low-rank coal chars, the SO₂ sorption of the latter under the test conditions is the same.

6.0 RECOMMENDATIONS

- Activated char should be prepared and tested as adsorbant for gaseous mercury species.
- Activated char should be prepared and tests as a medium for water cleanup.

7.0 PAPERS AND PRESENTATIONS

Young, B.C.; Olson, E.S.; Knudson, C.L.; Timpe, R.C. "Activated Carbons from North Dakota Lignite and Leonardite," *ACS Preprints—209th ACS National Meeting 1995*, 40 (2), 280.

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This cover stock is 30% post-consumer waste
and 30% pre-consumer waste, and is recyclable.