WESTERN REGION FLY ASH SURVEY

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Abstract

A questionnaire to determine the factors influencing fly ash production and usage in the Western Region was sent to generating stations in Colorado, Wyoming, Utah, Montana, North Dakota, New Mexico, and Arizona, and to power plants using coal from any of these States. David Goss of Public Service of Colorado and Co-Chair of the Western Region Ash Group refined the questionnaire. Topics covered included: the type and source of coal, combustion system, scrubbers, average percent ash, % CaO, % LOI, class of fly ash, tons fly ash produced, disposed, used, category of usage, transport, marketers, and market area. Coal-fired plants using Western Region coal in Nebraska, Nevada, West Texas, Minnesota, and Washington are included in this report. Of the 70 coal-fired generating stations in these States, 38 responded (Figure 1) and are reported in the results of this survey.

Coal Areas in the Western Region

Several major coal basins lie within the Western coal region of the United States including: the Williston, Powder River, Green River, Uinta (Wasatch Plateau), San Juan, and Black Mesa basins (Figure 1). Coal-bearing sequences in these areas are of Late Cretaceous/Eocene age. During the Late Cretaceous, foreland basins stretched along the western margin of the Western Interior seaway and most of the Late Cretaceous coals developed in nearshore environments (Table 1). Tertiary-age coals in the Western Region are not associated with nearshore environments; rather they developed in inter-montane fluvial and lacustrine environments.

Western Region coals vary in ash content. This region's Late Cretaceous coals have higher ash content than those deposited in the Tertiary, particularly those developed in fluvial environments (Table 1). Many of these Tertiary coals were developed in raised mires that tend to have less flooding and, therefore, less influx of inorganic material. In the Tertiary, Washington's Eocene coals are an exception and were deposited in a lower-delta plain environment, similar to the Late Cretaceous coals, with concurrent volcanic activity. Most of this region's Late Cretaceous coals developed during regressive cycles brought on by increased sediment supply from tectonically active highlands. Volcanic activity also added inorganic material, mainly silica, reaching the mires as windblown or stream deposits. These differences in depositional environment are reflected in the ash percent and chemical properties of the ash by-products produced from electrical generation.

Western United States Coal Electrical Generation and Production

The American Coal Ash Association (ACAA) includes all of the Western United States, Hawaii, and Alaska in Region VI (Figure 1). In 1998, Region VI produced approximately 10.9 million MT of CCPs of which about 2.04 million MT (18 percent) was used. This is lower than the 29 percent usage of CCPs in the United States.

Within ACAA's Region VI is a major coal producing area, the Western Region. In 1998, this region (Figure 1) surpassed the eastern Appalachian coal region as the leading coal-producing area in the United States. In part, the demand for western low-sulfur coal was fueled by the low cost and the sulfur emissions reduction requirements of the 1990 Clean Air Act Amendments (CAAA) for low-sulfur coal. Demand for western coal also was enhanced in 1998 by a large drop in hydroelectric generation in regions west of the Mississippi. Conversely, coal production in the appalachian and Interior regions was hindered by mild weather and bringing back on-line significant amounts of nuclear-powered capacity (Freme and Hong, 2000).

Although western coals are considered low sulfur, 44 percent of the units at the power plants surveyed have some form of scrubber system. Both units at the Springerville plant (Arizona) have dry scrubbers and none of this fly ash is marketed. The Wyodak No.1 unit (Wyoming) has a dry scrubber and all of the ash from this unit is placed in disposal ponds. The Hayden (Colorado), Rawhide (Colorado), and Stanton (North Dakota) plants all have spray dryer scrubbers that contaminate the fly ash and effectively make this material unusable. At the Sherburne station, two units have wet scrubbers and the third unit has a spray dryer scrubber. In all three units, the alkaline fly ash is used as a sorbent in the scrubber to replace all or a portion of the lime. All fly ash from this plant is high in SO_3 and does not meet ASTM C618 (1995) specifications (Michael R. Thomes pers. communication, 2000). Units 1 and 2 at Cholla (Arizona) have wet venturi scrubbers and the fly ash is contaminated. The remaining plants surveyed have scrubber systems that do not contaminate the fly ash. Fly ashes contaminated by FGD material are not classified as C or F fly ash and are not included in the following discussion.

Classification of Western coal fly ash

Lignite, subbituminous, and bituminous coals are burned at Western power plants and produce both Class F and Class C fly ash. The Class C fly ashes typically come from Tertiary coals that developed in fluvial environments (Table 1). The following ash and CaO percentages are plant averages. Twelve surveyed plants burn Powder River Basin (Wyoming) subbituminous coal, producing Class C fly ash (Figure 2) that typically have >15 percent CaO. Eocene Fort Union Powder River Basin coals are low in ash (4–5 percent), but the Dave Johnston plant burns Wasatch Formation coal from the Powder River Basin that has 8 percent ash. Fly ash from this plant is much lower in CaO (8 percernt) than the Fort Union Formation ashes that range from 21–30 percent CaO. The Dave Johnston material is the only low-calcium Class C fly ash in this group. The Arapahoe station burns various Powder River Basin coals and some Green River coal, probably lowering the CaO content. The remaining Class C fly ash is produced from Williston Basin lignite (North Dakota). Coal Creek station burns Fort Union Formation coal from a different bed than the Powder River Fort Union coal. The percent ash is higher than in any of the Powder River coals and the percent CaO of the fly ash is lower.

Class F fly ashes are produced from subbituminous and bituminous coals from the Green River Basin, Uinta Basin, Wasatch Plateau, San Juan Basin, Black Mesa area, and Washington (figures 1 and 3). These coals are consistently higher in ash than those producing Class C fly ash and were developed in lagoonal back barrier or interdeltaic mires (Table 1). The Uinta and San Juan Basin fly ashes have very low CaO (<5 percent). San Juan Basin coals produce the greatest quantities of ash, especially Fruitland Formation coals. Fly ash from this formation has some of the lowest CaO percentages of all reported in the survey (Figure 3). None of the Class F fly ashes in this group would be classified as high calcium, but Wasatch Plateau fly ash is consistently higher in percent CaO. A few stations that replied to the survey burn several types of coal and produce both Class F and Class C fly ash. These stations are not shown on figures 2 and 3.

Generally, plants reporting Class C fly ash have less than one percent LOI content. The Arapahoe (Colorado) and Sheldon (Nebraska) stations are exceptions with two percent LOI and 30 percent LOI, respectively. Cyclone burners at Sheldon are a major reason for the high LOI content. Sheldon fly ash is only used for soil modification.

Plants reporting Class F fly ash show more variation in LOI content. Nine of these plants have less than two percent LOI. The three Utah plants have from three percent to 12.5 percent LOI. Only the Hunter plant, with three percent LOI, has minimal use of fly ash and the rest is disposed. Cherokee (Colorado) averages 6.25 percent LOI and both Cameo (Colorado) and W.N. Clark (Colorado) have very high LOI content. The W.N. Clark fly ash is collected with the bottom ash in a silo. This material is used for deicing winter roads and occasionally as a soil stabilizer. None of the Cherokee station fly ash is used because of the high percentage of inert material, a constituent of the LOI (Dave Goss personal communication, 2000).

Fly Ash Market in the Western United States

Market Areas

Most power plants use ash marketers to sell their fly ash. Major marketers in this region are ISG Resources, Boral Materials Technologies, Mineral Solutions, Phoenix Cement, and Depauw Fly Ash. The western United States fly-ash market is limited by the distance to market, a result of relatively few large population centers (Figure1) and power plants that are often located near coal sources, rather than near large cities (Figure 1). Although true for most of the plants surveyed, several plants are located near two large populations centers, Minneapolis and Denver (Figure 1). Black Dog and High Bridge (Mineral Solutions) sell all but a minor amount of their fly ash in the Minnesota and Wisconsin markets, and Riverside sells 50 percent of their fly ash. The remaining plants (A.S. King, Sherburne County) have ash that either is contaminated by FGD or is produced from a blend of coal and petroleum coke, not meeting classification standards. Seven of the Colorado plants surveyed are near Denver. Three plants are within the Denver Metropolitan area, but only the Cherokee plant sells a large percentage (51 percent) of their fly ash. The Pawnee plant (Boral), east of Denver has markets in Nebraska, Kansas, and Colorado and sells 65 percent of the fly ash they produce. The remaining plants in Colorado sell little or no fly ash because of scrubber system contamination, collection of fly ash with bottom ash, or LOI content. All of the fly ash from Centralia in Washington is sold. ISG markets this fly ash in nearby Portland and Seattle and has storage facilities in these cities (Tom Fox ISG personal communication, 2000).

Arizona and California have a high population density (Figure 1) and are market areas for the Mojave, Apache (Boral), Cholla, Four Corners, and San Juan (Phoenix Cement) power plants. Except for San Juan, which was just beginning to market fly ash in 1998, all of these plants sell greater than 50 percent of their fly ash in Arizona and California as well as New Mexico, Utah, and Colorado. These plants produce Class F fly ash that is desirable in this area to prevent ASR in concrete. Although Utah is a relatively populated State, very little fly ash from the Utah power plants surveyed is sold because of inconsistency or low quality. Wyoming is very sparsely populated and only the Jim Bridger plant (ISG Resources) markets a large percentage (86 percent) of the Class F fly ash produced. The Naughton plant produces Class F also, but because of unburned organic material only 17 percent of the fly ash is marketed. Scrubber contamination, quality problems, or distances to market are factors affecting the fly ash usage from other Wyoming plants. North Dakota and Montana are also sparsely populated States. Two of the three plants in this area sell 25-35 percent of the fly ash produced. The cold climate limits the construction season and the cost to transport fly ash to more populated areas with longer seasons is prohibitive. The two plants in West Texas (DePauw Fly Ash) sell 100 percent of their Class C fly ash in Texas, New Mexico, Oklahoma, and Kansas.

Fly Ash Quality

The classification and quality of fly ash can be very important in determining whether fly ash is sold. Fly ash contaminated by FGD by-products is a major factor. Seven of the 38 responding power plants list FGD material collected with some or all of the fly ash as the reason their material is not sold, amounting to 1.44 million MT of disposed fly ash.

Percent LOI, either inert material or unburned carbon, is a limiting factor as well. Fly ash with LOI greater than 6 percent does not meet ASTM C 618 (1995) specifications. Low NO_x burners burn the coal at a lower temperature, leaving more carbon in the ash. Twenty-five of the reporting power plants have one or more units with low NO_x burners. However, when the respondents were asked if low NO_x burners played a role in making their fly ash unmarketable, only three of the 25 thought it was a factor. LOI content influences the fly ash color. Color can be very important for some applications and markets. Light-colored fly ash is preferred for cement or concrete products, particularly in California. The type of unburned carbon remaining in the fly ash is important when AEA is used for frost resistance. This can be a limiting factor for some fly ash usage in the northern States of the Western region.

ASR is a problem throughout the Western United States because of the aggregate available, and many western States limit the CaO content of the fly ash that can be used when the aggregate is potentially reactive. Class F fly ash is often preferred to limit the effects of ASR.

Transportation and Storage

Although the Western United States and particularly Wyoming have a good railroad network, very few marketers transport fly ash by rail. The Wyoming Jim Bridger plant (ISG Resources) is an exception shipping 90 percent of the fly ash sold to markets in California and Utah. The San Francisco Bay area is a major consumer of this fly ash, and ISG has fly ash storage facilities here (Tom Fox personal communication, 2000). The Four Corners plant (New Mexico) ships 60 percent of their fly ash sold by truck to a railhead several kilometers away where it is then shipped to California and Arizona markets. The Arizona Cholla plant ships 40 percent by rail to California. Phoenix Cement markets both the Four Corners and Cholla fly ash and has storage facilities in each major market area (Ron Helms personal communication, 1999). More fly ash is produced in the winter months especially in the northern States, but without storage facilities, this fly ash can't be saved for the summer months when there is a construction market. The fly ash must have characteristics that give it greater marketability to justify the expense of storage facilities.

Coal Creek (North Dakota) ships 40 percent of its fly ash by rail to nearby markets of Montana, North Dakota, Minnesota, and Canada. The Gerald Gentleman plant (Nebraska) uses rail to ship 18 percent of their fly ash to the Denver market. Most of the fly ash shipped by rail is Class F and is from plants located great distances from their markets. These producers ship large quantities making rail transport economically viable. Fly-ash producers using truck as their main mode of transportation are either closer to their markets, do not have rail load out facilities, or can not market large enough quantities of fly ash to make rail transport economically viable.

Summary and Conclusions

Both Class F and Class C fly ash are produced in the Western United States. The Class C fly ash is generally high in calcium and produced from subbituminous and lignite coals from the Powder River and Williston basins, respectively. Class F fly ash is low in calcium and produced from bituminous and subbituminous coals in the Green River, Wasatch, San Juan, Black Mesa, and Centralia regions.

Fly ash has many characteristics making it attractive as an admixture to concrete, including strength, lowering heat of hydration, workability, and resistance to ASR. Use of fly ash lowers the cost of the concrete, saves energy, and reduces CO_2 production. In the Western United States, 1.509 million MT of fly ash is sold for concrete products and 0.4 million MT is sold for use in cement. Other major uses include backfill (662 thousand MT), stabilization (182 thousand MT), and road base (109 thousand MT). Class C fly ash has more diverse in application but there is more Class F fly ash sold.

Several factors influence the marketing of fly ash in the Western United States:

- Quality, consistency, and class of fly ash are very important in determining usage and market area;
- FGD contamination restricts a significant amount of fly ash from use;
- LOI content can limit usage because of unburned carbons (AEA) or color characteristics;
- Transportation infrastructure is important, but truck transport is preferred except when large quantities can be sold to distant markets;
- Storage facilities at different locations in the market area increase sales, but are only economically viable if the quality of the product is in demand;
- Western fly ash usage can't be entirely predicted by proximity to market; the quantity sold and market area is often determined by the quality of the fly ash. Fly ash produced at a power plant some distance from a market but of superior quality has the potential to be shipped greater distances, such as the fly from the Jim Bridger plant. Fly ash of lesser or inconsistent quality from a plant near a market may have limited usage, such as the Utah fly ash. In this respect, fly ash can act as a specialty mineral instead of a commodity mineral.

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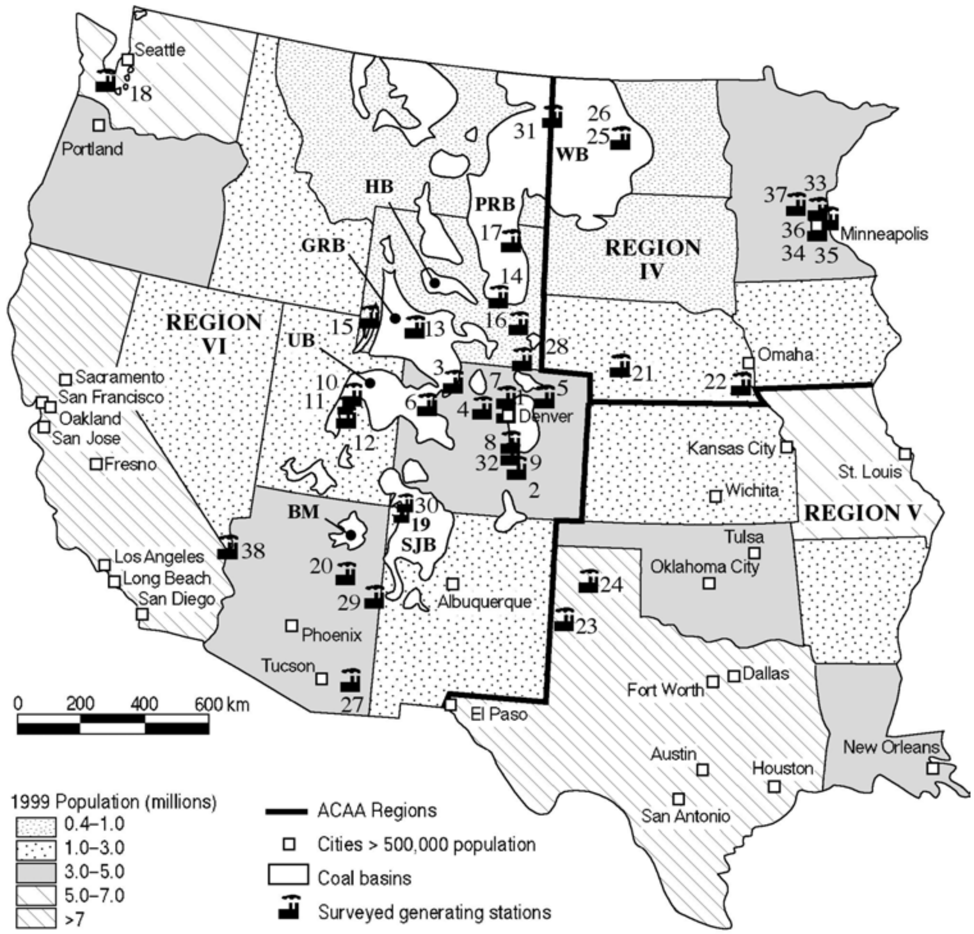
Table 1. Western US coal basin- depositional environment and ash content.
Basin abbreviation in parenthesis is shown on Fig. 1.

Area	**Basin**	**Formation**	**Age**	**Coal Type**	**Depositional environment**	**Ash content***	**Stations**	**Reference**
Canada, North Dakota	Williston (WB)	Fort Union	Paleocene	Lignite	Fluvial-deltaic raised swamp	Medium	3	Flores & Keighin 1999
Wyoming	Powder River (PRB)	Wasatch	Eocene	Subbituminous	Fluvial	Medium	1	Flores & Bader 1999
		Fort Union	Paleocene	Subbituminous	Fluvial-raised swamp	Low	16	
S. Central Wyoming	Hanna (HB)	Hanna	Paleocene	Bituminous	Low-lying fluvial	Low-medium	1	Flores *et al*. 1999
		Ferris	Paleocene	Bituminous		Medium		
SE Wyoming, NE Colorado, NW Utah	Green River-Hams Fork (GRB)	Fort Union	Paleocene	Subbituminous	Low-lying, fluvial	Medium		Flores & Bader 1999
		Williams Fork	Late Cretaceous	Bituminous	Interdeltaic	Medium	7	
		Adaville	Late Cretaceous	Subbituminous	Interdeltaic	Low	1	
NE Utah, W. Colorado	Uinta-Wasatch Plateau (UB)	Black Hawk	Late Cretaceous	Bituminous	Lagoonal, back-barrier	Medium	3	
NW New Mexico, SW Colorado	San Juan (SJB)	Fruitland	Late Cretaceous	Subbituminous-Bituminous	Lower delta, back-barrier	High	2	
		Menefee				Medium-high	2	
Arizona	Black Mesa (BM)	Wepo	Late Cretaceous	Subbituminous	Lower delta, back-barrier	Medium	1	
Washington	Centralia	Skookumchuck	Eocene	Subbituminous	Back-barrier	Medium	1	

*Low Ash- <8%, Medium Ash 8-15%, High Ash >15%



Generating station number and name:

1 Arapahoe
2 Comanche
3 Hayden
4 Cherokee
5 Pawnee
6 Cameo
7 Valmont
8 Martin Drake
9 R. D. Nixon
10 Carbon
11 Huntington
12 Hunter
13 Jim Bridger
14 Dave Johnston
15 Naughton
16 Laramie River
17 Wyodak
18 Centralia
19 Four Corners
20 Cholla
21 Gerald Gentleman
22 Sheldon
23 Tolk
24 Harrington
25 Coal Creek
26 Stanton
27 Apache
28 Rawhide
29 Springerville
30 San Juan
31 Lewis & Clark
32 W. N. Clark
33 A. S. King
34 Black Dog
35 High Bridge
36 Riverside
37 Sherburne County
38 Mohave

Figure. 1. Western United States with ACAA regions, Western Region coal basins, surveyed generating stations, and population data. Abbreviations for coal basins are defined in Table 1 from Hoffman, 2002. Printed with permission from the Geological Society of London.

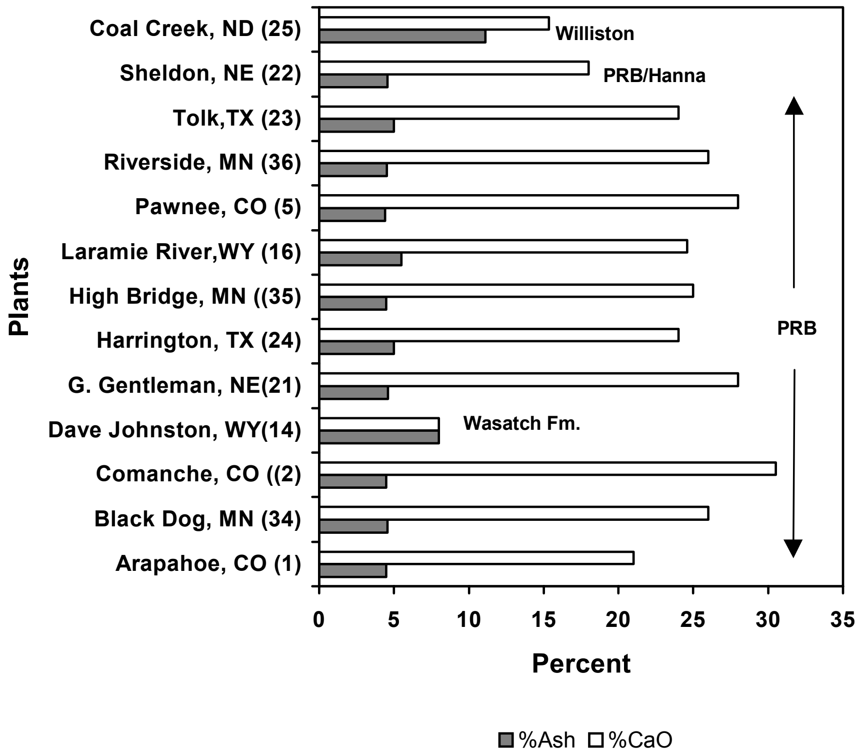


Figure 2. Average percent ash from coal and average percent CaO from fly ash for plants reporting Class C fly ash. Number in parenthesis identifies plant on Figure 1. Modified from Hoffman, 2002. Printed with permission from the Geological Society of London.

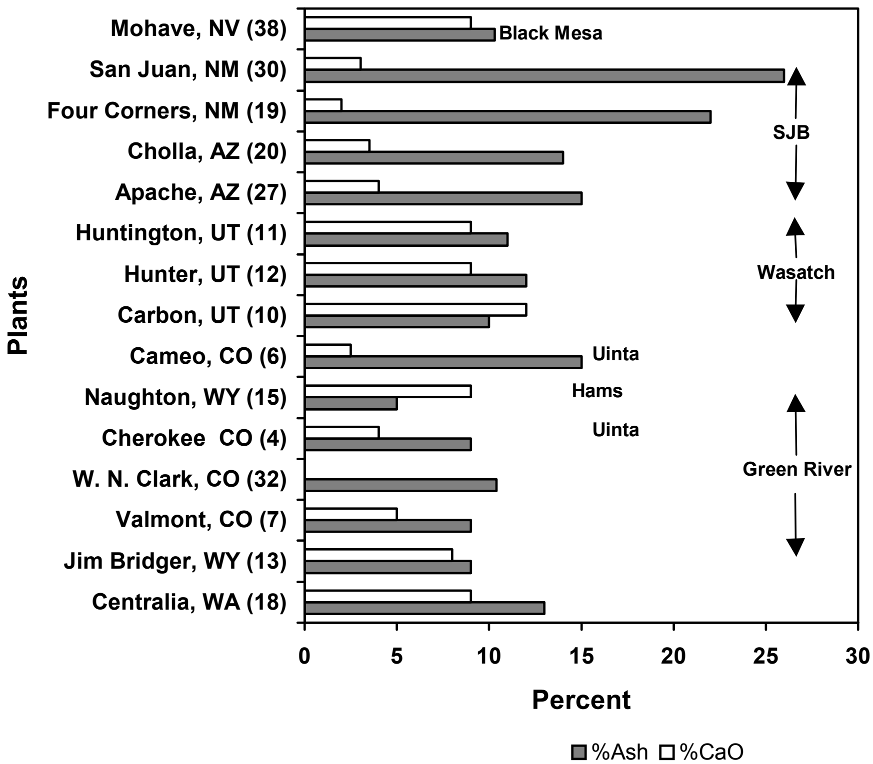


Figure. 3 Average percent ash from coal and average percent CaO from fly ash for plants reporting Class F fly ash. Number in parenthesis identifies plant on Figure 1. Modified from Hoffman, 2002. Printed with permission from the Geological Society of London.